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SAN FRANCISCO BAY BRIDGE

REPORT OF

The Hoover-Young San Francisco Bay Bridge Commission

— TO —

THE PRESIDENT OF THE UNITED STATES

— AND —

THE GOVERNOR OF THE STATE OF CALIFORNIA

AUGUST, 1930

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PART A

August 6, 1930.

HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION

To

The President of the United States:

The Governor of the State of California:

Subject: Report of Commission.

THIS REPORT CONSISTS OF THREE PARTS:

PART A—Consists of outline of the authorization for the Commission and outline of its duties, conclusions and recommendations.

PART B—Consists of the minutes of the meetings, brief outline of the discussions, statement pertaining to the interests of navigation as prepared by the Army members of the Commission, statement of the problem as it affects national defense prepared by the Navy members of the Commission, and a brief of the report of the Division of Highways of the State of California.

PART C—Report in full of the State Division of Highways, including maps and appendices.

In accordance with instructions from the President of the United States and the Governor of the State of California, this Commission, designated as the Hoover-Young San Francisco Bay Bridge Commission, was convened at Sacramento, California, on October 7, 1929.

The Commission held its first meeting at the office of the Governor of the State of California in the State House at Sacramento, at 10 o'clock a.m. on the seventh day of October, 1929, and was greeted in person by the Honorable C. C. Young, Governor of the state.

The Commission continued in session during the remainder of the day and adjourned to San Francisco where it resumed its sessions in the State Building, Civic Center, on October 8, 1929. It adjourned on October 9, 1929, and continued in recess until July 22, 1930, when it reassembled at the call of the chairman.

At its session on the seventh of October, the following resolution was passed:

(a) "That the problem of this Commission is to endeavor to work out a solution of the state and interurban traffic needs between the

counties of San Francisco and Alameda across San Francisco Bay, reconciling these with the needs of national defense and the national interests of navigation. It is hoped that a type of structure and a location can be arrived at which will meet the traffic needs and which can be accepted by all parties at interest. The question of the cost of the proposed bridge must be given fullest consideration to the end that the solution must be economically possible."

The problem of a crossing across the bay between San Francisco and Alameda counties has been under much discussion for many years. Definite conclusions were impossible because of lack of sufficient information as to foundation conditions as well as incomplete data as to the traffic situation. The Commission therefore at once proceeded to take the steps to secure this information and the following resolution was adopted:

(b) "*Resolved,* That the Department of Public Works of the State of California be asked to make an engineering, economic and traffic study and furnish the Commission with all data obtained for the purpose of determining the relative value of the several proposed locations for a connection between San Francisco and Alameda counties."

At the call of the chairman the Commission met in the Governor's office in San Francisco at 10 a.m., Tuesday, July 22, 1930. All members were present.

The Commission then proceeded with a careful detailed study and analysis of the report of the Division of Highways and upon the conclusion of this held public hearings at which all parties so desiring were heard.

The period between October 9, 1929, and July 22, 1930, was employed in securing the information in accordance with the last mentioned resolution. This information was obtained under the supervision of the Department of Public Works, Division of Highways, State of California, by Mr. C. H. Purcell, state highway engineer, and his engineering staff.

The work of borings was made possible by an appropriation by the city and county of San Francisco. The traffic survey was made under the direction of L. S. Ready, consulting engineer of the Division of Highways. Plans and estimates of proposed structures were prepared under the direction of Mr. Chas. E. Andrew, bridge engineer. The information thus obtained was most thorough and complete and was prepared in a manner readily accessible for study by the Commission. These officials are to be highly commended for the excellence of their work.

In view of the announced policy of the War Department indicating absence of objection to the locations south of Hunter Point, the Commission has limited its detailed discussion to sites north of Hunter Point. The site immediately south of the line from Hunter Point to Alameda is feasible from an engineering viewpoint.

The Commission has come to the following

CONCLUSIONS

(a) To meet the present and future needs of the several communities a crossing for traffic between San Francisco and the East Bay cities is necessary.

(b) Consistent with meeting the traffic needs and engineering requirements the type and location of a bay crossing should be such that it will not unreasonably obstruct future navigation nor cause serious interference with or constitute a serious menace to the operations of the Navy in time of war.

(c) Because of the limitations, cost of construction and operation a vehicular tunnel under the bay is inadvisable.

(d) As indicated by the rock explorations the only location upon which to base a high level bridge is on a line from Rincon Hill to Goat Island.

(e) A bridge on the location designated as Location No. 4, from Rincon Hill via Goat Island thence parallel to the Key Route mole, is practicable from an engineering standpoint. It is economically feasible under a proper fiscal plan and will adequately serve the needs of transbay traffic.

(f) The bridge should conform to the following specifications:

(g) The bridge shall provide at least six lanes for vehicular traffic and in addition five lanes for interurban and heavy automobile truck traffic.

(h) The bridge between San Francisco and Goat Island shall consist of not more than four main spans, the westerly one of which shall have a horizontal clearance of not less than 1750 feet between fenders.

(i) The vertical clearance of the two center spans shall be not less than 214 feet above M.H.H.W. at the center of the spans, and this height shall be maintained for approximately 500 feet on either side of the center of the span, and the minimum vertical clearance at the San Francisco pier head line shall be 180 feet above M.H.H.W.

(j) The main channel span in that portion of the bridge between Goat Island and the east shore shall have a minimum vertical clearance of 180 feet above M.H.H.W. and a minimum horizontal clearance of 600 feet between fenders. Consideration should be given in the final plans to a minimum clearance of 700 feet between fenders.

(k) The final design should be such that it will conform with the scenic beauty of San Francisco Bay.

(l) The details of construction of the bridge structure is the function of the State of California working through the California Toll Bridge Authority.

Consideration of traffic distribution on both sides of the bay is of prime importance and should be worked out in cooperation with the authorities of the municipalities in interest.

(m) A right of way across Goat Island must be obtained from the Navy Department and be approved by Congress.

Under the provisions of the federal law after legislative authorization by the State of California, the plans of the bridge must receive the approval of the Chief of Engineers, War Department, and of the Secretary of War before construction is begun.

The legislative authority of the state for the construction of the bridge is vested in the California Toll Bridge Authority. In order that the bridge may be constructed it is necessary that the Bridge Authority authorize and direct its construction.

RECOMMENDATION

The Commission having given due consideration to national defense and the needs of commercial navigation and in the light of all facts recommends the approval of a bridge upon Location No. 4 provided the clearances specified are adhered to.

Respectfully submitted.

Mark L. Requa
Mark L. Requa, Chairman

George T. Cameron
George T. Cameron, Vice Chairman

Luther E. Gregory
Rear Admiral Luther E. Gregory, C.E.C., U.S.N. Ret'd.

W. H. Standley
Rear Admiral W. H. Standley, U.S.N.

Brigadier General G. B. Pillsbury, U.S.A.

E L Daley
Lieutenant Colonel E. L. Daley, U.S.A.

Arthur H Breed
Senator Arthur H. Breed

Charles D Marx
Charles D. Marx

C. H. Purcell
C. H. Purcell, Secretary

PART B

MINUTES OF MEETINGS

Minutes of Meeting of San Francisco Bay Bridge Commission Held in Sacramento October 7, 1929

The members of the Commission met first in the office of Governor Young in Sacramento on October 7, 1929, and were welcomed by the Executive. At this informal meeting, the Commission unanimously elected Mark L. Requa to be chairman of the Commission.

At the conclusion of the welcome by the Governor, the Commission met in the office of Mr. B. B. Meek, Director of Public Works. A full attendance of the Commission was present. The chairman called the meeting to order and stated that the question of the scope of the investigation to be conducted by the Commission would be the first order of business. After discussion, the following resolutions were passed:

Moved by Major Daley and seconded by Senator Breed,

> "That the problem of this Commission is to endeavor to work out a solution of the state and interurban traffic needs between the counties of San Francisco and Alameda across San Francisco Bay reconciling these with the needs of national defense and the national interests of navigation. It is hoped that a type of structure and a location can be arrived at which will meet the traffic needs and which can be accepted by all parties at interest. The question of the cost of the proposed bridge must be given fullest consideration to the end that the solution must be economically possible."

Carried unanimously.

Moved by Professor Marx and seconded by Colonel Pillsbury,

> "Resolved that the Department of Public Works of the State of California be asked to make an engineering, economic, and traffic study and furnish the Commission with all data obtained for the purpose of determining the relative value of the several proposed locations for a connection between San Francisco and Alameda counties."

Carried unanimously.

It was also understood that this traffic study would specifically take in the points of Telegraph Hill, Rincon Hill, Potrero Point and Hunter Point.

On motion of Mr. C. H. Purcell and seconded by Major Daley, Mr. George Cameron was unanimously elected vice chairman of the Commission. Mr. C. H. Purcell was asked and consented to act as secretary of the Commission and W. M. Stuart of San Francisco as assistant secretary.

The meeting adjourned at 4.05, to meet in the office of Governor Young in San Francisco at 9 a. m., October 8, 1929.

October 8, 1929.

The Commission met at 9 a. m. in the office of Governor Young in the State Building, San Francisco. A full attendance of the Commissioners was present.

It was stated by the chair that the first business should be making up of an agendum and after discussion the following was prepared:

1. Personal inspection by members of Commission of localities of interest—Major Daley to make up itinerary.
2. Borings—Secretary to determine amount that can be spent on this question and proceed accordingly.
3. Traffic movement—State Highway Department to issue cards to travelers across San Francisco Bay to determine points of arrival, etc.
4. Collection of earthquake fault data. Secretary to secure data from Engineer Kirkbride of Southern Pacific Company and Professor Lawson.
5. Question of possibility of double deck bascule lift span.
6. Accuracy of report that local shipping association does not desire a bridge north of Hunter Point, and, if true, how much influence this association may exert.
7. Press to be notified that Commission will receive communications from parties interested relating to various bridge schemes.

Major Daley submitted the following itinerary to the Commission, which was approved, with the reservation that the various points need not be visited in the order set down. The itinerary submitted by Major Daley was as follows:

1. Visit Telegraph Hill.

   Observe fairway between ferry station and Goat Island. Note relation of street system to possible bridge terminal.

2. Visit Rincon Hill.

   Observe fairway between pierhead line and Alameda Mole. Note street system as above.

3. Visit Potrero Point.

   On the way study land routes. At point, observe fairway. Note street system.

4. Visit Hunter Point.

   On the way study land routes, and at Hunter Point observe fairway in direction of Alameda Mole and Bay Farm Island. Note street approaches.

5. Proceed to San Mateo Bridge.
   Note lift span and cross to east shore. Note Mills Air Field in passing.
6. Proceed to Oakland Airport.
   Note relation of airport to Bay Farm Island and Alameda Mole.
7. Proceed to Alameda Airport.
   Note interference of proposed terminal of Location No. 1 with air operations. Observe area set aside for proposed Army Base and the limits of the proposed Navy Base.
8. Visit Alameda Mole.
   Observe proposed routes from bridge terminal.
9. Inspect Webster street tunnel.
10. Go to Cragmont, Berkeley.
11. Visit Goat Island.

The following resolution proposed by Professor Marx and seconded by Major Daley was carried unanimously:

"*Resolved*, That the studies by the State Department of Public Works shall be forwarded from time to time as completed, to each member of the Commission.

"*Resolved*, That the next meeting of the Commission will be held subsequent to the distribution of all the data so gathered, it being the understanding of the Commission that the gathering of this data will require at least from sixty to ninety days.

"*Resolved*, That the Commission adjourn on Thursday of the present week, subject to reconvening at the call of the chairman."

Rear Admirals Gregory and Standley presented to the meeting a statement showing the position of the Navy at this time in connection with the proposed crossing of San Francisco Bay.

It was decided that the Commissioners would visit Goat Island on adjournment of the meeting, which took place at 12.15. The chair announced that the meeting would resume the next morning at 9 o'clock in the same office.

October 9, 1929.

The Commission met at 9 a.m. in the office of the Governor, State Building, San Francisco, and proceeded to carry out the itinerary considered on the 8th instant.

This inspection was completed at 7 p.m. of this day.

October 10, 1929.

The Commission met at 9 a.m. in the office of the Governor, State Building, San Francisco, discussed the inspections made, and agreed that no definite conclusions could be drawn until the information was made available from the engineering, economic, and traffic studies to be made by the Department of Public Works of the State of California.

The meeting adjourned at 12 noon, subject to call of the senior member.

MINUTES OF SECOND SESSION

July 22, 1930.

Meeting called to order by Chairman Mark L. Requa at 10.15 a.m., Board Room of the State Highway Commission, State Building, San Francisco. All members present.

The Commission decided that it would first consider in executive sessions the data prepared by the Department of Public Works, Division of Highways, State of California; that the engineers of the department would appear before the Commission commencing the afternoon of July 22 and that the Commission would continue executive sessions until the matter had been fully explained and consideration given to the data presented. Also that as soon as the Commission had become familiar with the data, opportunity would be given for all interested parties to present their statements.

2 p.m. Closed meeting with Professor Louderback, Dean of the College of Literature and Arts and Professor of Geology of the University of California.

3 p.m. Lester S. Ready discussed traffic report.

4.50 p.m. Meeting adjourned until 10 a.m. July 23.

July 23, 1930.

Meeting called to order at 10 a.m. All members present.

Chas. E. Andrew, state bridge engineer, discussed borings and an exhibit of boring samples and rock cores taken on the various locations was shown the Commission.

Resolution:

> "*Resolved*, That Locations 1, 1-A, 1-B and 1-C be eliminated from further consideration on account of foundation conditions."

Motion laid over for further consideration.

2.05 p.m. General discussion on navigation and clearances.

Resolution offered by Admiral Standley:

> "*Resolved*, That it is the sense of this Commission that route designated as Location No. 4 is most suitable for a bridge crossing north of Hunter Point and that this Commission proceed with the discussion as to whether or not such a bridge should be recommended by this Commission."

Not voted upon.

5.00 p.m. Meeting adjourned until 10 a.m., July 24.

July 24, 1930.

Meeting called to order at 10.25 a.m. All members present except C. H. Purcell.

General discussion on subject of inviting general public. Chairman Requa to frame letter to be sent to interested parties.

Resolution offered by Admiral Standley:

> "*Resolved*, That Locations 1, 1-A, 1-B, 1-C and 2 be eliminated from further consideration on account of foundation conditions."

Passed.

Chas. E. Andrew continued discussion relative to design.

Chairman Requa read a press release.

Adjourned at 12.50 p.m. to reconvene at 10 a.m., Monday, July 28.

July 28, 1930.

Meeting called to order by Chairman Mark L. Requa. All members present.

10.15 a.m. Open meeting at which were present city officials and representatives of civic organizations from municipalities interested in the problem before the Commission.

Hearing adjourned at 11.30 a.m.

The following submitted by Admiral Standley as descriptive of the function of this Commission:

"That the function of this Commission is not to design a structure but to devise an acceptable crossing of the bay."

12 noon. Executive session. Adjourned at 12.30 p.m.

2.30 p.m. Meeting with James B. McSheehy.

3.15 p.m. Hearing with Mr. Frank White, chief engineer of the State Harbor Commission.

4 p.m. Hearing with Mr. Gallagher and Captain Edwards of the Matson Navigation Company.

5 p.m. Adjourned to reconvene at 10 a.m., July 29.

July 29, 1930.

Meeting called to order by Chairman Mark L. Requa, at 10 a.m. All members present.

10.30 a.m. Continued meeting with Mr. Gallagher and Captain Edwards of the Matson Navigation Company.

11.30 a.m. Executive meeting.

Resolution:

"That when this Commission finishes its report and the same is signed, the duties of the Commission are completed."

Passed.

2.30 p.m. Hearing with Mr. M. M. O'Shaughnessy, city engineer of the city of San Francisco.

3.15 p.m. Hearing with Mr. Helmers of the firm of Siems-Helmers, Inc., contractors of St. Paul, Minn.

4 p.m. Executive meeting.

Admiral Gregory was appointed subchairman of the Commission to handle the compilation of the Commission's report for submission to the President of the United States and Governor of California.

Resolution:

"That location No. 3 be eliminated from further consideration."

Passed.

Resolution:

"That the time of adjournment be fixed as noon, August 6."

Passed.

Adjourned 5 p.m. to reconvene at 10 a.m., July 30.

July 30, 1930.

Meeting called to order at 10.15 a.m. All members present.

Hearing with delegation from Alameda County.

12 noon. Hearing with Mr. Frickstad and Mr. Anderson, officials of the city of Oakland.

2.30 p.m. Hearing with Board of Harbor Commissioners of the city of Oakland.

4 p.m. Executive meeting.

5.00 p.m. Meeting adjourned to reconvene at 10 a.m., July 31.

July 31, 1930.

Meeting called to order at 10 a.m. All members present.

Discussion of bridge design.

Following brief submitted by Admiral Standley:

"I desire to present to the Commission for consideration certain inherent objections to a bay bridge of the type and in the position shown as Location No. 4 and designated as "The Rincon Hill-Goat Island Bridge" site.

(1) It must be obvious even to a layman that a bridge across San Francisco Bay north of Hunter Point will be objectionable from the standpoint of the navigation of vessels under and around this bridge particularly in thick or foggy weather. The Navy holds this objection in common with all shipping interests.

(2) There are also objections to this bridge from a national defense standpoint which are peculiarly naval and which should be considered by this Commission. These objections arise from the fact that, in case of a war in the Pacific, San Francisco Bay will necessarily become the main operation base for practically all operations in the Pacific, and that part of the bay which must be entered under this bridge will be the center of all naval activities including not only the battle fleet but also all auxiliaries and merchant vessels used in support and maintenance of the fleet. The number of vessels involved in these activities will reach into the hundreds. This bridge will not only increase the hazards and difficulties of handling and loading these vessels but it will also create a more or less real menace to these activitiess and to the security of this country in case of a national emergency—that is, in case of catastrophe as a result of which this bridge through its entire length should be thrown off its piers and into the bay, the bay to the southward would be entirely closed to all shipping and all vessels then in the lower bay would be interned for a more or less indefinite period and it is conceivable that it would demobilize the entire fleet. Such a catastrophe is conceivable but not probable; it is possible and not entirely improbable that spans of this bridge might be damaged to such an extent as to drop either one or both ends into the bay, or a pier might be destroyed which would drop connecting ends of two spans. While this would necessarily cause inconvenience and increase congestion, it would not be a vital menace to naval operations as there would still be usable channels.

No bridge north of Hunter Point is free from naval objections, but a bridge on Location No. 4, "Rincon Hill-Goat Island," is the least objectionable from the standpoint of national defense, and while the naval members of this Commission can not commit the Navy Department to any action on this proposed bridge and site they can state, from the standpoint of the use of the Navy in national defense, that a bridge of the type stated and on the designated site, Rincon Hill-Goat Island, is the least objectionable bay crossing north of Hunter Point.

For the reason stated above the Navy members strongly recommend that there be inaugurated in connection with the building of this bridge and the obtaining of Goat Island from the government, a project to complete dredging a deep water channel (35 feet M.L.W.) between Goat Island and the East Bay shore line. This would add one more channel into the lower bay area which is below the bridge and greatly lessen the menace of this bridge from the standpoint of national security."

This was fully discusssed by the Commission.

11.30 a.m. Subject of tubes was discussed.

Resolution offered by General Pillsbury and seconded by Senator Breed:

> "It is the sense of this Commission that the proposed tube be eliminated from consideration."

Passed unanimously.

11.55 a.m. Economic discussion.
Adjourned at 12.45 p.m. to reconvene at 10 a.m., August 4.

August 4, 1930.

Meeting called to order at 10.15 a.m. All members present.
Reading of correspondence.
Discussion of bridge structure as redesigned by Chas. E. Andrew, with increased horizontal and vertical clearances.
Resolution moved by Admiral Gregory, seconded by Professor Marx:

"*Resolved,* That it is the sense of this Commission that the only practicable site for a high level bridge across the bay is Location No. 4 from Rincon Hill to Goat Island."

Unanimously passed.
Resolution moved by Admiral Gregory, seconded by Colonel Daley:

"*Resolved,* That the bridge between San Francisco and Goat Island shall consist of not more than four main spans, the westerly one of which shall have a horizontal clearance of not less than 1750 feet between fenders."

Unanimously passed.
Resolution moved by Admiral Gregory, seconded by Professor Marx:

"*Resolved,* That the vertical clearance on the two center spans shall be not less than 214 feet above M.H.H.W. at the center of the spans, and that this height shall be maintained for approximately 500 feet on either side of the center of the span, and that the minimum vertical clearance at the San Francisco pierhead line shall be 180 feet above M.H.H.W."

Passed unanimously.
Adjourned 5.30 p.m. to reconvene at 10 a.m., August 5.

August 5, 1930.

Meeting called to order at 10.15 a.m. All members present.
Discussion of horizontal and vertical clearances between Goat Island and Oakland.
Letter from Oakland Port Commissioners referred to Senator Breed, Admiral Gregory, and C. H. Purcell for drafting suitable reply.
Resolution offered by Senator Breed, seconded by Professor Marx and General Pillsbury:

"*Resolved,* That the main channel span in that portion of the bridge between Goat Island and the east shore should have a minimum vertical clearance of 180 feet above M.H.H.W. and a minimum horizontal clearance of 600 feet between fenders. Consideration should be given in the final plans to a minimum clearance of 700 feet between fenders."

Carried unanimously.
Resolution offered by Colonel Daley, seconded by Admiral Gregory:

"The details of construction of the bridge structure, beyond the determination of the principal features specifically covered by

this Commission is the function of the State of California working through the California Toll Bridge Authority."

"Consideration of traffic distribution on both sides of the bay is of prime importance and should be worked out in cooperation with the authorities of the municipalities in interest."

Carried unanimously.

Resolution offered by General Pillsbury, seconded by Senator Breed and Colonel Daley:

"We recommend that the final design be such that it will conform with the scenic beauty of San Francisco Bay."

Carried unanimously.

Resolution offered by Admiral Gregory, seconded by Professor Marx:

"*Resolved,* That this Commission place itself on record as expressing its appreciation of the cooperation of the Department of Public Works of the State of California, and to the excellent work done by C. H. Purcell, State Highway Engineer, in general charge of the work, and assistants: Chas. E. Andrew, Bridge Engineer; Lester S. Ready, Consulting Engineer on Traffic Studies; Everett L. Walsh, Field Engineer on Borings; also to the supervisors of the city and county of San Francisco in furnishing funds for defraying a portion of the cost of the exploratory work in the bottom of the bay."

Carried unanimously.

Discussion of proper set up and wording for report to be prepared under the supervision of Admiral Gregory.

Adjournment at 6 p.m. to reconvene at 10 a.m., August 6.

August 6, 1930.

Meeting called to order at 10 a.m. All members present.

Discussion was entered into at once relative to the form of the report to be submitted, together with the nature of the final recommendations to be made.

Resolution offered by General Pillsbury, seconded by Colonel Daley:

"That the general outline of the report as submitted by Admiral Gregory be adopted."

Carried unanimously.

Communications from the Port Commissioners of Oakland were read, discussed, and a reply drafted and mailed.

The report submitted by Admiral Gregory was thereupon discussed in detail, and all features agreed upon unanimously.

Report was written and signed by all members.

Commission adjourned sine die at 5.30 p.m.

BRIEF OUTLINE OF SPECIAL DISCUSSIONS

2 p.m., July 22, 1930.

Meeting was called to order by Chairman Mark L. Requa in the Board Room of the California Highway Commission, State Building,

San Francisco, for a closed hearing at which were present geologists and engineers.

Professor Louderback, Dean of the College of Literature and Arts and Professor of Geology, University of California, testified as to the general character of substrata formation in the San Francisco Bay area and gave discourse in connection with the action and effect of earthquakes and probable results.

Points brought out:

(1) Earthquakes affect surface strata, but it is not known to what depths there would be damaging action.

(2) Structures founded on solid rock would undoubtedly be safer than those founded on plastic materials.

(3) The analysis of samples of materials is not of prime importance, due to the fact that it does not show the compactness of the material in its original state.

(4) No known active faults in vicinity of proposed locations. No surface indications which would indicate that such faults are present. However, any quarry opened up in this vicinity is full of fractures, but this does not necessarily indicate the presence of active faults.

(5) Surface indications have no connection with the depth of underlying rock, due to wind-blown material, water erosion and sedimentation.

10.15 a.m., July 28, 1930.

The meeting was called to order by Chairman Mark L. Requa in the Board Room of the State Railroad Commission, State Building, San Francisco, for an open hearing at which were present city officials and representatives of civic organizations of the cities of San Francisco, Oakland, Berkeley, Alameda, and Emeryville.

Mr. Requa opened the meeting with a history of developments up to date, the taking of borings to determine foundation conditions on the various proposed routes, and the elimination from an engineering and economic standpoint of all routes with the exception of Location No. 4 —Rincon Hill to Goat Island and thence to the Key Route mole. Previous meetings had been executive and the Commission was now inviting the municipalities and others interested to present their views on the matter.

Marshall C. Baer, port attorney of the Board of Port Commissioners, Oakland, requested an opportunity to appear before the Commission at a special session for the purpose of discussing their problems. He was advised that the Board of Port Commissioners would be heard on Wednesday, July 30, at 10 a.m.

Mr. M. Callahan, assistant city engineer of the city of San Francisco, advised that his department had not been given an opportunity to study the report; therefore, they were not in position to make any recommendations or endorsement of the site proposed. He requested additional time in which to complete a study and then submit comments, if time would permit.

Mr. Alfin N. Nelson, assistant city attorney of the city of Oakland, stated that he had been instructed to inform the Commission that the city of Oakland was in favor of any location the Commission sees fit to adopt and that they were willing to cooperate in every way possible.

Mr. Clifton E. Hickok, city manager of the city of Alameda, stated that they were naturally disappointed in the selection of the proposed

site and requested that they be allowed to study the report, particularly with reference to the manner in which it was proposed to handle vehicular traffic from the city of Alameda. The Commission informed them that further discussion of this question would be held on Wednesday, July 30, at 10 a.m. in conjunction with representatives of the city of Oakland.

Mr. Requa replied that after listening to the presentations of the municipalities, it was his conclusion they desired a better understanding of the technical details and that they were desirous of special hearings before the Commission for the purpose of discussing their particular problems. Also that the Commission was in full agreement with such a procedure and that their requests would be granted at a later date.

Supervisor A. J. Rossi, acting mayor of San Francisco, commended the Commission on the wonderful progress shown to date, and stated that it was his belief that the recommendation would receive the wholehearted support of the officials of the city of San Francisco.

Mayor Schaefer of the city of Alameda expressed himself as disappointed with developments to date and requested that further consideration be given to the handling of the situation with respect to the city of Alameda.

Mr. Anderson of the street department of the city of Oakland requested that they be given an opportunity to study the report in detail and given at least thirty days in which to submit any reflection on the eastern terminus of the bridge as regards handling traffic within the city limits. Mr. Purcell replied that he had already discussed this matter with their city engineer, and the problem of taking care of traffic before reaching and after leaving the bridge was a detail that could be worked out as an after determination of the adoption of a particular site for the bridge regardless of the location.

Mr. H. D. Webber, representing the Oakland Business District Association, requested that an opportunity be presented for a discussion of the details of traffic distribution.

State Senator Roy Fellom, representing the Central Council of Civic Clubs, comprising some forty San Francisco improvement organizations, also as author of the bill creating the Toll Bridge Authority, stated that the organizations which he represented were unanimously in favor of the work the Commission was accomplishing, and expressed confidence that the problem would be quickly solved. He expressed his personal appreciation of the businesslike manner in which the Commission was functioning.

Mr. George S. Young, representing the Engineers Club of the East Bay District, expressed confidence in the Commission and stated that his organization would render whatever help possible in the solution of the problem.

Mr. John F. Shea, representing the Hotel Men's Association of Northern California, stated that they would endorse any type of bridge or any site which the Commission decided upon.

Mr. E. M. Broderson, representing the Alameda Improvement Club, stated that while the first consideration to be given was the selection of a location that was feasible from an engineering standpoint, the fact must not be overlooked that traffic from Alameda must be served. He also requested that consideration be given to the granting of a further hearing to representatives of the city of Alameda after a com-

plete study of the report submitted by the Department of Public Works had been made.

Mr. Hollis R. Thompson, representing the Berkeley Chamber of Commerce, expressed confidence in the Commission and pledged support of his organization in the considerations of the Commission. He requested that his organization be granted an opportunity to study the report.

State Senator Maloney of San Francisco expressed confidence in the Commission and in the way the problem was being handled.

Mr. Francis, representing the Northern Improvement Club of Oakland, expressed their satisfaction at the selection of the site proposed.

Mr. F. H. Amin, representing the Down Town Association of San Francisco, expressed confidence in the Commission and stated that the members of his organization had not had an opportunity to express themselves but would do so after an investigation of full data presented to them.

Mr. Frank White, chief engineer of the State Harbor Commission, stated that the Board of Harbor Commissioners was entirely in accord with the method in which the Bridge Commission had approached the subject, and presented a wire from the chairman to that effect.

Supervisor J. B. McSheehy of San Francisco congratulated the Commission on the wonderful progress made. He gave a history of the previous committees endeavoring to settle this problem. Mr. McSheehy requested an opportunity to appear before the Commission for the purpose of presenting some data he had assembled on the construction of a combination tube and bridge. His request was granted and the time set for 2.30 p.m. on the same day.

2.30 p.m., July 28, 1930.

Meeting open to the press.

Mr. James B. McSheehy was present for the purpose of submitting data which he had assembled on the construction of a tube and bridge. He requested that the records show that he was appearing as a private citizen and not as supervisor of the city and county of San Francisco. He related the history of the hearings conducted by the board of supervisors of some twenty-eight applicants for franchises to build bridges across the bay, the investigations made by the board, and presented a written report to the Commission on this subject.

The construction of the tube portion was on the same plan as the construction of the tube under the Oakland Estuary. He submitted an estimated cost for this construction at $38,000,000, contemplating four lanes of automobile traffic on an upper deck and three lanes of interurban traffic on a lower deck.

3.15 p.m., July 28, 1930.

Closed meeting.

Mr. Frank White, chief engineer of the State Harbor Commission, appeared at the request of the Bridge Commission.

Questions pertaining to the docking facilities and past and future developments were asked. Some of the developments of this conference were:

1. The largest ships now entering San Francisco Harbor dock at Pier 22, the proposed location of the bridgehead. Mr. White stated that these ships could dock elsewhere.

2. Pier 45 is the limit for possible future pier construction to the north. To the west of Pier 45 the territory has been set aside for park purposes.

3. About nine miles of available water front, of which about one-half has been permanently developed.

4. Present maximum dock which is 1300 feet in length would accommodate the largest ship now in operation and is located to the north of the proposed bridge site.

5. That if the bridge were constructed at the proposed site, the docks within 1000 feet of the bridgehead would not be considered satisfactory for docking large ships.

6. If the bridge should be constructed and replace ferryboats, additional space would be available for docking steamships.

7. That the Board of Harbor Commissioners feels no apprehension in regard to the building of a bridge.

4.00 p.m., July 28, 1930.

10.15 a.m., July 29, 1930.

Closed meeting.

Mr. Gallagher and Captain Edwards of the Matson Navigation Company appeared at the request of the Commisison to present their viewpoints on the hazards to navigation should a bridge be constructed at the proposed location.

Mr. Gallagher expressed himself as being against the construction of any bridge north of Hunter Point, but also stated that he realized the demands of the public warranted such a structure and navigation could adjust itself to the additional hazard.

The subject was discussed in detail in regard to the possibility of ships negotiating the bridge while docking in the close proximity of the proposed bridgehead.

They were particularly concerned with the horizontal and vertical clearance of the bridge and expressed preference for a horizontal clearance of 2000 feet or greater and a vertical clearance that would allow passage of the largest ship now in operation. He stated that a ship of the size of the *Malola* could maneuver within a 1700-foot clear opening.

The discussion also centered around the possibility of this bridge being an additional hazard fifty or sixty years in the future.

2.30 p.m., July 29, 1930.

Mr. M. M. O'Shaughnessy, city engineer of the city of San Francisco, appeared before the Commission and stated that he had not had sufficient time to study the report of the Department of Public Works in detail. He further stated that he was not appearing to criticize the work of the Commission but that he had one suggestion to make in the construction of a crossing—that a tube be given consideration, his contention being that the height necessary to construct a bridge would make it objectionable from a shipping standpoint. At frequent intervals it would be necessary for the larger ships to pass this bridge in going into dry dock. In addition, consideration should be given the crossing of the bay that will serve the greatest amount of traffic.

It was Mr. O'Shaughnessy's contention that Location No. 1 would serve traffic more economically than Location No. 4. Colonel Daley

asked the question as to whether in his opinion there was a possibility of buses replacing interurban trains for short hauls. His reply was that he did not believe that buses would ever be used for this purpose on account of inability to handle the peak traffic. In answer to a question as to consideration of Hunter Point, Mr. O'Shaughnessy stated that his consideration of Hunter Point would come only after all other possibilities had been eliminated, on account of the distance involved.

3.15 p.m., July 29, 1930.

Mr. Helmers of the firm of Siems-Helmers, Inc., contractors, of St. Paul, Minnesota, now engaged in the construction of the Southern Pacific Bridge across Carquinez Straits, appeared at the request of the Commission for the purpose of relating his experience and the hazards encountered on the present construction, which in general would be similar to the laying of foundations across San Francisco Bay.

In answer to a question Mr. Helmers stated that he believed a structure across San Francisco Bay, as designed by the Department of Public Works and submitted as a part of their report, was entirely feasible, and that he would feel no hesitation in bidding on its construction.

Mr. Helmers went into detail in explaining the methods of construction used by his company in the construction of the Southern Pacific Bridge.

10.15 a.m., July 30, 1930.

The following delegation from Alameda County appeared before the Commission for the purpose of discussing traffic details and connections to the proposed bridge from the east side of the bay:

C. E. Hickok, city manager of city of Alameda.
Chas. E. Quigley, Taxpayers League, Oakland.
Capt. W. B. Voortmeyer, vice president and chairman Airport and Harbor Committee, East Side Consolidated Civic Clubs.
E. L. Vander Naillen, delegate from East Bay Engineers Club.
Clarence L. Traver, president of Alameda Chamber of Commerce.
T. E. Caldecott, mayor of Berkeley.
Harry Goodridge, city engineer of Berkeley.
R. V. Dell, chairman Harbor Committee, Oakland Real Estate Board.
Waldo R. Norris, Key System Transit Co., Oakland.
Hans K. Krunan, property owner, 4051 San Pablo avenue.
J. P. Wright, property owner, Alameda, California.
Victor L. Schaefer, mayor of Alameda.
A. R. Linn of the Western Air Express.

Mr. Hickok, city manager of Alameda, acted as spokesman and stated that he had received a copy of the engineers' report the day before, but had not been able to digest all of the information presented therein. Although disappointed at the selection of the Goat Island location they assured the Commission that they were not appearing as a protest committee on the selection of this route, but what they were particularly interested in at this time was the question of traffic distribution from Alameda to the bridgehead. He submitted figures as to distance to be traveled showing that Alameda travel would be obliged to cover a distance of 9.5 miles to the bridgehead, against 4.7 miles if

Location No. 1 were selected. The train time over the proposed bridge would be 23 minutes against the present ferry service of 24 minutes.

The population of Alameda was stated as being approximately 40,000. He also stressed the fact that not only Alameda would be affected by this longer distance, but also East Oakland and South Oakland. It was also his contention that the commuters' rates would not be reduced, and that there was the possibility of an increased rate.

The question of ship clearance on the Goat Island location was also brought up. Mr. Hickok agreed that the borings on Location No. 1 showed that the rock formation was not feasible for a high level bridge, and brought up the point that a combination tube and bridge was feasible.

Mr. Purcell was called upon to clear up some of the points advanced by Mr. Hickok. Mr. Purcell reviewed a portion of the detailed study that had been made, of the taking of borings and investigation of traffic distribution. He also stated that in making their recommendation they had taken no particular community into consideration, but had worked on the plan from the standpoint of traffic centers and the serving of the largest amount of vehicular and interurban traffic. As to taking care of commuter traffic from Alameda, he stated such a problem could be worked out by the communities involved in cooperation with the state, the details of which would most likely expedite travel over that which Mr. Hickok claims.

Mr. Clarence L. Traver, president of the Alameda Chamber of Commerce, stated that the people of Alameda were disappointed in the selection of the Goat Island route, but if the recommendation were made for that location they would work toward the building of the bridge.

The question was raised as to what body was to bear the expense of making the necessary connections with Alameda. Mr. Requa replied that such matters would have to be taken care of by the cities involved. Also, it was Mr. Requa's opinion that in the future elevated thoroughfares would serve this territory.

The question of tubes was brought up and the delegation was advised of the investigations made and the reasons for eliminating this type of structure in favor of the high level bridge.

Mr. A. R. Linn of the Western Air Express stated that he thought it the duty of the Commission to furnish the people of Alameda with facts regarding routes of traffic and other information pertaining to the subject that would definitely assure them of a connection being made and that it was his hope that the people of Alameda would be unanimously behind the Commission in its final selection.

Mr. Requa called their attention to the fact that this would be a free bridge upon the redemption of bonds.

Mayor Schaefer of Alameda stated that the problem of his city was not vehicular but commuter service, and unless they were adequately taken care of he was afraid that they would lose many of their residents.

The question was brought up as to the possibility of routing the bridge from Goat Island to the Southern Pacific Mole. The Commission informed them that this possibility had been eliminated on account

of the greatly increased cost due to the depth to suitable foundations, and the impairment of the Oakland Harbor.

Mayor T. E. Caldecott of Berkeley expressed his appreciation of the selection of Location No. 4.

Mr. Harry Goodridge, city engineer of Berkeley, spoke in favor of the bridge. He made the statement that it was his opinion that the automobile ferries from Berkeley would continue to operate if a bridge were constructed.

Captain W. B. Voortmeyer, vice president and chairman of the Airport and Harbor Committee of the East Side Consolidated Civic Clubs, spoke in favor of Location No. 4 and expressed the opinion that from an engineering and geographical standpoint the selection was the best that could be made.

12, noon, July 30, 1930.

Mr. W. M. Frickstad, city engineer, and Mr. Anderson, commissioner of streets of the city of Oakland, submitted a written brief covering their problem, which is strictly a question of traffic handling.

Their attention was called to the distribution of the gas tax to the counties, which money could be spent within incorporated cities.

The question of taking care of traffic if Location No. 5 (Hunter Point-Alameda) were adopted, was brought up and Mr. Frickstad replied that it would still require some readjustment, but that without having given the matter previous consideration it was his opinion that the amount of money involved would be less.

2.30 p. m.

The following members of the Board of Harbor Commissioners of the city of Oakland appeared for a discussion of their problem:

Ex-Governor Geo. C. Pardee, member of the Board of Harbor Commissioners.

Sherwood Swan.

G. B. Hegardt, port manager of Port of Oakland.

Arthur H. Abel, assistant chief engineer.

Marshall C. Baer, port attorney.

Ex-Governor Pardee acted as spokesman and stated that they had not examined the report of the engineers in detail. He submitted a brief outlining their position in the matter and from the standpoint of the Harbor Commission they object to the construction of a bridge at Location No. 4 on account of the hazard to shipping in moving under the bridge from one dock to another.

The question of clearances was brought up with the result that the board was to study the report further and advise in writing on Monday, August 4th, as to the horizontal and vertical clearances that would be acceptable to them.

The discussion proved very lengthy and detailed as to the procedure of handling traffic and as to whether the clearance of the proposed span would take care of present and possible future traffic.

Ex-Governor Pardee stated that they were registering objections to the location at this point as a Board of Port Commissioners and not as private citizens. Also, that they were not willing to compromise irrespective of whether the people of Oakland were desirous of having the bridge constructed at this location.

STATEMENT SUBMITTED BY THE ARMY MEMBERS AS TO THE INTERESTS OF NAVIGATION

San Francisco Bay is one of the outstanding natural harbors of the world. At a number of places on the bay a great terminal port could be established. It has been established at San Francisco. Enormous sums are invested in the mercantile and financial establishments necessary to the conduct of the business of the port, and it is contrary to the public interest to incur the great expense necessary to reestablish them in another place.

The available water front of San Francisco is limited. The northern frontage of the city is exposed to ocean swells coming through the Golden Gate, and has been dedicated to park purposes west of Fort Mason. About six miles of frontage is available for terminal development. The most desirable and the most intensively used section of the water front is that centering on the foot of Market street, nearest the business, financial, and hotel districts of the city.

The city of Oakland has recently constructed extensive port terminals which have resulted in a rapid growth of its ocean shipping. It has a well developed program for the extension of its facilities. Its Harbor Commissioners rightly demand that nothing be done which will restrict the future usefulness of these terminals.

At Hunter Point, near the southern extremity of the San Francisco water front, there is located a drydock capable of receiving the largest ships afloat. This is the only large drydock available on the Pacific coast south of Puget Sound.

There has grown a strong public demand for a bridge across San Francisco Bay north of Hunter Point. The borings made for this Commission on various lines indicate that the most feasible site for such a bridge is from Rincon Hill via Goat Island to the Key Route Mole. This site crosses the most desirable and the most utilized section of the San Francisco water frontage. All traffic for the present water terminals at Oakland and vessels bound for the Hunter Point dry dock or docks south of Rincon Hill must pass it. Any bridge constructed on this site should have such horizontal and vertical clearances that it will not unreasonably obstruct present and future navigation.

In arriving at these clearances, it is necessary to bear in mind that a strong tidal current, up to three miles per hour, runs in the fairway between Goat Island and San Francisco. Before it has straightened itself out and gained maneuvering headway, a vessel leaving a dock may be carried a considerable distance by the tide. It is considered unsafe to undock a large vessel within half a mile of a bridge which the vessel can not clear.

The clearances must be those available at high water. The cost of delays to wait low water in order to pass the bridge are an intolerable burden on the shipowner. In view of the variations in draft and trim, and the possibility of stages above mean higher high water, no prudent shipmaster will take a vessel under a bridge unless he has a reasonable margin in excess of his mast height.

A recent investigation into the commerce of a large eastern port, whose business is predominately freight traffic, shows that the average size of the freight ships entering the port has doubled in the last

twenty years. The largest vessels entering the port of New York in 1830 were of 600 tons, with 18 feet of draft; they had increased by 1860 to 3000 tons with draft 21 to 24 feet, and in 1884 to 8000 tons, draft of 26 feet and over. At the present time a vessel of 75,000 tons is under consideration. Many small ships and very few large ships are now idle. There is no ground for presuming that the progress in the size of ships has stopped. On the contrary the present trend to mass production, with large concentrated freight offerings, indicates that the limit of growth is in the far distant future. It is impossible to predict the size of ships that will be generally employed in commerce thirty years hence when most of the present bottoms will be replaced by new construction. Because of the impossibility of predicting the future requirements of shipping, the War Department has had the policy that no bridge should be constructed north of Hunter Point. The expanding needs of automobile traffic have made it necessary to review this policy and to determine the clearances, which, so far as can now be foreseen, will not unreasonably obstruct future navigation.

Having in view the growth in the size of ships during the past forty years, it is reasonable and conservative to predict that the ordinary ocean carrier forty or fifty years hence will be from 600 to 800 feet in length, with masts ranging up to 180 feet; and that 1000 foot ships, with mast height well in excess of 200 feet, will frequently use the port. To serve this commerce, without destroying the most valuable and useful portion of the water front of the port of San Francisco, it is essential that any bridge constructed between Goat Island and San Francisco have a minimum vertical clearance of 180 feet above mean higher high water (186 feet above the datum plane of lower low water) at the San Francisco pierhead line, and a maximum clearance of 214 feet in the middle spans to afford access of larger vessels to the San Francisco water front south of the bridge, Oakland Harbor, and the Hunter Point drydock. The minimum horizontal clearance adjacent to the San Francisco pierhead line, to assure safety in undocking, should be at least 1750 feet.

It is to be distinctly realized that one ship now afloat, the *Majestic,* could not reach the Hunter Point drydock, even with the clearance proposed. There is every probability that there will be built in the future a considerable number of vessels with even higher masts. It is idle to speculate on the means by which such vessels could be made to pass under the bridge, since the obvious remedy for the owner will be to dock the vessel at another port. So far as now can be foreseen, the number of such vessels will not be sufficient to render the place of their overhaul a matter of general concern.

In view of the obstacles created by the piers of any bridge, the congestion always to be expected in the fairway, the influence of strong tidal currents, and the possibilities of fog, the channel spans in the main fairway between San Francisco and Goat Island must be of the maximum length reasonably practicable.

The Commission has before it a telegram from a competent bridge engineer indicating that it is practicable to span the fairway between San Francisco and Goat Island with a bridge having a single mid-channel pier. With this construction, advantages to navigation, and to the future of San Francisco, from the greater freedom and reduced

hazard of navigation, are so great that this proposal should receive fullest consideration before final plans for the bridge are prepared.

The portion of the bridge between Goat Island and the Oakland water front will interfere to some degree with the expansion of the water terminals of Oakland Harbor. A passage for ocean freighters must be provided through this bridge to provide for the movement of vessels between piers of the harbor. The maximum practicable clearance, because of foundation and grade conditions and character of commerce, appears to be a vertical clearance of 180 feet above mean higher high water and a horizontal clearance of 600 to 700 feet. These clearances will afford sufficient facilities for changing berth for a long period of time. Access to any portion of Oakland Harbor is possible by other routes.

This discussion of any bridge at the location is based on the premise that the bridge will be so designed that no earthquake reasonably to be anticipated will result in its destruction. Aside from any consideration of navigation, no other type of structure should be built.

STATEMENT SUBMITTED BY THE NAVY MEMBERS AS TO THE RELATION OF A BAY CROSSING TO NATIONAL DEFENSE

We desire to present to the Commission for consideration certain inherent objections to a bay bridge of the type and in the position shown as Location No. 4 and designated as "The Rincon Hill-Goat Island Bridge" site.

(1) It must be obvious even to a layman that a bridge across San Francisco Bay north of Hunter Point will be objectionable from the standpoint of the navigation of vessels under and around this bridge, particularly in thick or foggy weather. The Navy holds this objection in common with all shipping interests.

(2) There are also objections to this bridge from a national defense standpoint which are peculiarly naval and which should be considered by this Commission. These objections arise from the fact that, in case of a war in the Pacific, San Francisco Bay will necessarily become the main operation base for practically all operations in the Pacific, and that part of the bay which must be entered under this bridge will be the center of all naval activities including not only the battle fleet but also all auxiliaries and merchant vessels used in support and maintenance of the fleet. The number of vessels involved in these activities will reach into the hundreds. This bridge will not only increase the hazards and difficulties of handling and loading these vessels but it will also create a more or less real menace to these activities and to the security of this country in case of a national emergency—that is, in case of catastrophe as a result of which this bridge through its entire length should be thrown off its piers and into the bay, the bay to the southward would be entirely closed to all shipping and all vessels then in the lower bay would be interned for a more or less indefinite period and it is conceivable that it would demobilize the entire fleet. Such a catastrophe is conceivable but not probable; it is possible and not entirely improbable

that spans of this bridge might be damaged to such an extent as to drop either one or both ends into the bay, or a pier might be destroyed which would drop connecting ends of two spans. While this would necessarily cause inconvenience and increase congestion, it would not be a vital menace to naval operations as there would still be usable channels.

No bridge north of Hunter Point is free from naval objections, but a bridge on Location No. 4, "Rincon Hill-Goat Island," is the least objectionable from the standpoint of national defense, and while the naval members of this Commission can not commit the Navy Department to any action on this proposed bridge and site they can state, from the standpoint of the use of the Navy in national defense, that a bridge of the type stated and in the designated site, Rincon Hill-Goat Island, is the least objectionable bay crossing north of Hunter Point.

For the reason stated above the Navy members strongly recommend that there be inaugurated in connection with the building of this bridge and the obtaining of Goat Island from the government, a project to complete dredging a deep water channel (35 feet M.L.W.) between Goat Island and the East Bay shore line. This would add one more channel in to the lower bay area which is below the bridge and greatly lessen the menance of this bridge from the standpoint of national security.

BRIEF OF REPORT OF THE STATE OF CALIFORNIA, DEPARTMENT OF PUBLIC WORKS, DIVISION OF HIGHWAYS, TO THE HOOVER-YOUNG BAY BRIDGE COMMISSION.

Mark L. Requa, chairman.
George T. Cameron, vice chairman.
Rear Admiral Luther E. Gregory, U. S. N.
Rear Admiral W. H. Standley, U. S. N.
Brigadier General G. B. Pillsbury, U. S. A.
Lieutenant Colonel E. L. Daley, U. S. A.
Senator Arthur H. Breed.
Charles D. Marx.
C. H. Purcell, secretary.

GENERAL

This report was compiled by the Department of Public Works of the State of California, Division of Highways, by C. H. Purcell, state highway engineer, and was transmitted to the Commission by B. B. Meek, director of public works.

This report is made in response to the following resolution, passed by the Bay Bridge Commission:

> "*Resolved*, That the Department of Public Works of the State of California be asked to make an economic and traffic study and furnish the Commission with all data obtained for the purpose of determining the relative value of the several proposed locations for a connection between San Francisco and Alameda counties."

CONTENTS

The report is divided into five major sections, as follows:

Section I—Traffic Survey.
Section II—Borings and Foundation Data.
Section III—Design Data.
Section IV—Economic Studies.
Section V—Summary and Conclusions.

The report in general covers all pertinent data having bearing on the location, construction and operation of a possible crossing of San Francisco Bay between San Francisco and Alameda counties. Studies were made of possible crossings on five general lines, as follows:

Location No. 1. A line drawn from Pier 34 on the San Francisco side to a point approximately 900 feet south of the end of the Alameda mole on the Oakland side. This line is approximately identical with Location No. 1 in the 1927 report.

Location No. 1-A. A line drawn from Pier 32 on the San Francisco side and passing through a point approximately 2300 feet south of the end of the Alameda mole to the Alameda shore.

Location No. 2. A line drawn from the foot of Sixteenth street in an easterly direction to the Alameda mole, following approximately the line designated as Location No. 2 in the 1927 report.

Location No. 3. A line drawn from the end of Pier 21 on the San Francisco side to the northwesterly portion of Goat Island, thence across Goat Island and the East Bay to the Key Route mole. This location is approximately identical with the line designated as Location No. 3 in the 1927 report.

Location No. 4. A line drawn from Pier 22 on the San Francisco shore and passing practically over the center of Goat Island, thence over the East Bay to the Key Route mole.

Location No. 5. A line drawn from Hunter Point on the west bay shore in a northeasterly direction toward Alameda.

Pertinent data on Locations 4 and 5 are given in this brief. Other locations are only touched upon because of the elimination of all lines except 4 and 5 by the Commission.

SECTION I

TRAFFIC SURVEY

1. Present traffic, vehicle and passenger.

In 1929 the auto ferries between San Francisco and the East Bay carried a total of 4,490,513 vehicles and 10,174,028 passengers, an increase over the previous year of 8.2 per cent. The center of vehicular traffic is near the Civic Center in San Francisco and near Moss and Oakland avenues in Oakland.

In 1929 the passenger ferries carried a total of 35,923,855 persons, almost 3 per cent less than the total for the previous year. The center of commuter traffic is near Fifth and O'Farrell streets in San Francisco and again near Moss and Oakland avenues in Oakland.

The center of traffic for both vehicular end commuter traffic in San Francisco is expected to continue near its present location. On the East Bay side the center of traffic may be definitely considered as tending to shift southward, although not at any great rate.

2. Probable future growth of traffic.

The volume of traffic to be expected will depend on several factors; *i. e.*, the growth of tributary population and auto registration, the tolls to be charged, the condition of the approach streets and provisions for parking and the diversion of traffic through the building of additional facilities, etc. The division of passenger traffic between interurban and privately owned vehicles will also depend on these factors. The effect of replacing ferries with a bridge is uncertain. It is apparent that reductions in vehicle tolls result in a general increase of traffic and has a tendency to divert passenger traffic from train service.

It is considered a safe and conservative estimate for the growth in vehicular traffic to use as a basis for computing probable earnings the following:

For several years, say to 1937, it will probably increase at the average rate of increase in auto registrations for the past five years—(5.8%).

For the rest of the period under consideration, it will at least equal the average rate of increase in population for the past forty years—(3%).

Interurban traffic can not be expected to increase materially and may possibly show a decrease.

It is expected that a bridge on Location No. 4 will divert 80 per cent of the vehicular ferry traffic, that the vehicular traffic will be increased 25 per cent immediately by the construction of the bridge, and that the yearly increase will be as stated above. It will also serve to carry interurban trains. The proposed bridge on Location No. 5 is expected to divert only 40 per cent of the ferry traffic and will not serve interurban train traffic.

3. Water borne traffic.

In 1929 there were 9887 vessels of all classes, excepting ferries, which would pass under a bridge on Location No. 4 to dock in San Francisco. At the present time there are 247 auto ferries and 48 freight ferries per day crossing this route. All but the freight ferries will be eliminated by the construction of the bridge.

In 1924 a total of 13,015 vessels entered the Golden Gate and the number has steadily increased to a total of 15,765 in 1929.

Location No. 4 does not cross the naval anchorages.

4. Distance and time of travel.

The weighted average distances and times of travel between the above mentioned centers of origin and destination of travel in Oakland and San Francisco are as follows:

	Interurban		*Vehicle*	
(a) Via present ferry service	11.114 mi.	58.204 min.	12.846 mi.	69.94 min.
(b) Via Loc. No. 4	12.457 mi.	47.910 min.	13.546 mi.	43.206 min.
(c) Via Loc. No. 5	17.742 mi.	62.238 min.	18.416 mi.	59.388 min.

SECTION II

BORINGS AND FOUNDATION DATA

Prior to the making of this report, very little was known of the character of foundation material in San Francisco Bay. The Commission, in order to obtain information for its needs, requested that such data be obtained by the Department of Public Works. As a result, a contract was let in January, 1930, to The Duncanson-Harrelson Co. of San Francisco to perform such foundation investigation. Borings were started January 30 and completed June 26, 1930. The method used was as follows:

A high pressure water jet was used to determine the depth to solid material on the various lines at various points throughout their length. After having determined the depth to solid material, a core drill was used to penetrate the hard material and to determine its character.

Forty-one jet borings and four core-drilled borings were made.

Samples were taken of all materials penetrated by the jet as well as by the core drill, and these samples are now on display in the office of the Bridge Department of the Division of Highways, Sacramento, California.

The equipment, and methods used, are fully described. Plate 14 in the report shows the general location of borings taken.

Logs of borings, profiles of the bay bottom, character of materials penetrated and depths to rock are shown as follows:

Profile, line 1, page 112.
Profile, line 1–A, page 116.
Profile, line 2, page 117.
Profile, lines 3–4, page 221.
Profile, line 5, page 122.

Briefly the general results of borings are as follows:

On *Location No. 1,* shale or rock is encountered at a depth of approximately 185 feet over a distance of 4000 feet from the San Francisco shore. From this point to the Alameda shore the depth to shale increases from 230 feet at a point 4000 feet from San Francisco shore to 350 feet depth near the Alameda shore.

On *Location No. 2,* the average depth to shale over the entire line is found to be over 300 feet.

On *Location No. 3,* shale is found between San Francisco and Goat Island at an average depth of 223 feet.

On *Location No. 4,* shale is found between San Francisco and Goat Island at an average depth of 168 feet. To the east of Goat Island, shale is found on lines 3 and 4 in the approximate location of the heavy piers at from zero to 250 feet depth.

On *Location No. 5,* shale was encountered in only one boring at a depth of 369 feet. The overlying material is, however, very firm clay with streaks of sand and gravel, and may be considered suitable for pile foundations under the structure necessary at this location.

Boring data indicates that Location No. 4 is by far the most feasible line for dependable foundations, as it is possible to found all heavy

piers on solid rock within depths considered reasonable from construction and design points of view.

Location No. 3 is the only other line on which it would be possible to reach rock with all heavy piers, and these piers would be at an average depth of 50 feet greater than on Location No. 4.

A detailed description and discussion of the materials encountered at each hole drilled may be found in the report.

The general character of material encountered was mud and varying types of soft or stiff sandy or gravelly clay, overlying shale and sandstone. Shale and sandstone beds are evidently of great thickness and increase in hardness as depth is gained. This shale and sandstone material is considered capable of sustaining foundation pressures of from 25 to 30 tons per square foot.

SECTION III

DESIGN DATA

The following general considerations are made in the design of the various structures.

1. Navigation clearances, general.

The general assumption as to vertical clearance is based upon the height of ships passing under the bridge in question. Reference is made to Chapter "C" of the 1927 report on "Harbor, Commerce and Ships," pages 31 to 39. Here a comprehensive statement, including mast and funnel clearances of the world's largest ships, will be found. It will be noted that the highest mast of any vessel entering San Francisco Bay is 177.5 feet, and that the highest listed ship on record, which has not entered San Francisco Bay, is 228 feet.

Data is given in the report under Section I, Traffic, establishing the fact that to date the highest mast on any ship entering San Francisco Bay is 177.5 feet above the water line and that the highest listed ship on record has a mast of 228 feet above the water line.

2. Vertical clearance.

With this data as a basis of assumption, the vertical clearance of the structure on Location No. 4 at center of the spans has been fixed at 220 feet for a distance of 600 feet. At the dock line the clearance has been fixed at 171 feet. For the span east of Goat Island a vertical clearance of 165 feet over the central 250 feet has been provided.

Location No. 5—Vertical clearance has been fixed at 150 feet over a distance of 300 feet at the center of the main channel span.

3. Horizontal clearance.

The horizontal clearance between pier fenders on Location No. 4 for the four main channel spans between San Francisco and Goat Island is 1600 feet. For the span east of Goat Island, a horizontal clearance of 600 feet is provided between pier fenders.

For Location No. 5, the horizontal clearance between pier fenders for one main channel span is 1100 feet.

4. Roadway and interurban requirements.

The Traffic Survey, Section I, together with the predictions made of traffic increases beyond 1940, establish the fact that a traffic of at least 16,000,000 cars per year may reasonably be expected during the life of a crossing structure.

It is desirable to carry all types of traffic over a centrally located bay crossing and, for this reason, it is considered necessary to provide slow traffic lanes for trucks only, these lanes to be independent of fast traffic.

It has been shown under Traffic Survey that approximately 12 per cent of the total vehicles crossing are trucks and 88 per cent are passenger cars and buses.

To accommodate a traffic of 16,000,000 vehicles without serious congestion, it is considered necessary to provide six traffic lanes, four of which are for fast traffic and two for truck traffic.

In Traffic Survey, Section I, it is shown that interurban traffic is not materially increasing and it is probable that it will not be necessary to provide for more than 40,000,000 interurban passengers per year for a considerable period of time. Two operation tracks, with an emergency track, are considered adequate to take care of this amount of traffic.

In view of these considerations, a double deck structure has been designed for Location No. 4, having a roadway 56 feet wide between curbs on the upper deck, which provides for six lanes of traffic. The roadway on the lower deck is to be of similar width providing for either four interurban tracks, or two operative interurban tracks, one emergency passing track and two vehicular lanes for truck traffic. This arrangement is provided to take care of probable traffic increase in the future over the 16,000,000 cars provided for on the upper deck.

On Location No. 5, an automobile traffic of approximately 40 per cent of that estimated for Location No. 4 is expected. No provision is made for interurban traffic. A single deck structure, having four traffic lanes, is provided.

5. Grades.

The question of limiting grades is one of great importance. A study has been made of grades now in operation in the Holland tubes under the Hudson River, Oakland Estuary Tube, Philadelphia-Camden Bridge and various other bridges, as well as operative grades on the highway system of the State of California. These studies lead to the conclusion that the maximum ascending grade should not exceed 3.5 per cent for highway traffic and 3 per cent for interurban traffic.

6. Loading and stresses.

Data for loading and stresses are shown on Plate 38 of the report, and conform in general with the requirements of the American Society of Highway Officials, and the American Society for Testing Materials.

Provision has been made for the resistance of earthquake stresses to the amount of 10 per cent of gravity for the foundations and 6 per cent of gravity for the superstructure.

7. General description of various structures.

These general descriptions may be found in the report.

SECTION IV

ECONOMIC STUDIES

1. Estimates.

Estimates of Costs for Structures on Locations 1, 3 and 4 are based on designs of equivalent service value, *i. e.*, six lanes of highway traffic on the upper deck and four interurban tracks and sidewalks on the lower deck.

Exceptions to the above are the single deck highway bridge on Location No. 4, and the Tube Line. These two structures provide for six lanes of highway traffic only.

Tables Nos. 36 to 42, inclusive, are cost estimates. All total and sectional cost items include, in addition to the actual construction cost, an item of 5 per cent for engineering and legal service, 5 per cent for contingencies, and 12 per cent for interest charges during construction.

2. Income, expense and bond retirement.

Traffic Survey, Section I, indicates that the population of the bay area has been increasing at the average rate of 3.06 per cent per year over the past fifty years. It also shows that the average rate of increase in auto registration for the bay area for the past five years has been 5.8 per cent per annum.

In computing income on any crossing structure, it has been assumed that this rate of increase, *i. e.*, 5.8 per cent will continue until 1937. The total number of cars crossing the bay in 1929 was 4,490,500. Applying the rate of 5.8 per cent increase annually, the figure of 7,070,000 is arrived at for 1937.

It is assumed that the crossing structure will be completed by the end of 1937 and that the added facility for crossing the bay will cause an immediate increase of approximately 25 per cent in traffic, bringing the total anticipated number of cars crossing in 1938 to 8,850,000. For 1939–1940, the rate of 5.8 per cent increase is further applied and brings the total car crossings by 1940 to 9,900,000; and for purposes of computing income, this figure is assumed at 10,000,000.

In the year 1940 the rate of autmobile increase is reduced to the population increase ratio, and is assumed at 3 per cent per annum. It is assumed that the average number of passengers per car will not exceed two persons.

All income tables are computed on the basis that bonds can be sold at 6 per cent and reserves can be invested during period of bond payment at 3 per cent.

As a basis for computing gross income on Locations 1, 3 and 4, 80 per cent of the total highway traffic crossing the bay is taken as being diverted to the bridge up to and including 1947, and 85 per cent thereafter.

On Location No. 5, 40 per cent of the entire highway traffic crossing the bay is taken as being diverted to the bridge.

Tables Nos. 43, 44, 45, 46, 48 are computed for Locations 1, 4 and 5. These tables show the gross yearly income, operating cost, bond interest requirements, total yearly cost and net income, reserve and bond retirement, for each bridge.

For Location No. 4, three tables are shown: Table No. 44 based on the present rate of tolls, Tables No. 45 and No. 46 being for reduced tolls.

3. General economic considerations.

(a) *General Traffic Utility.*

In the economic study and design of structures on the various lines an attempt has been made to make the traffic utility of the structures as nearly equal as their geographic positions would permit. The greatest traffic utility is attained by the structure which transports the maximum traffic between traffic centers with the least relative cost and congestion. The principal factors in such a consideration are cost of construction, cost of operation and effective distribution of traffic in San Francisco and Oakland. The first two considerations are represented by the estimated costs of construction and operation.

The matter of effective traffic distribution is determined generally by the answer to the question: Which site offers the quickest and most convenient delivery of travel from one traffic center to the other? The position of automobile and commuter traffic centers is shown on Plate 54.

(b) *Locations No. 1 and No. 4.*

A careful study of Locations No. 1 and No. 4 leads to the conclusion that very little choice, so far as transbay traffic distribution is concerned, exists between the two general lines. Both originate in Oakland at points practically the same distance from the gravity center of automobile and commuter traffic. Both terminate at relatively the same point in San Francisco. Traffic is taken and discharged in San Francisco south of Market street in a district where streets are wide and property of relatively low value. It is more or less self-evident that the growth of the city, and consequently its traffic, will be southward. The traffic centers are at present just a short distance north of Market street. The tendency of traffic center movement in a north and south direction is, therefore, toward the bridge head rather than away from it. Such a condition is considered desirable.

The discharge of passenger automobiles is carried well up toward the traffic center at Market and Van Ness and is, so far as possible, relieved of traveling over the busy streets between Fifth street and the bay. Truck traffic is discharged via a highway loop to the Embarcadero and water front streets where it, for a large part, originates and discharges. Traffic desiring to go to the large district south of Market street and to the Peninsula highways may do so over wide streets and with minimum congestion.

Commuters are discharged at loop stations close to Market street and only a short distance south of the commuter traffic center. The plan shown contemplates discharging main line train passengers at the First street loop station. As an alternate arrangement, a passenger terminal can be established on Rincon Hill, just off the bridge.

The interurban train loop is placed on relatively unimportant streets with a minimum of property damage, yet it is close to the desired point of distribution.

(c) *Location No. 5.*

Location No. 5 is not comparable with Locations 1, 3 and 4 in traffic utility because it does not carry interurban trains. The distance traveled between traffic centers is approximately 5.3 miles farther by Loca-

tion No. 5 than any of the other locations. Such a difference in distance would probably make it prohibitive for trucks to use this route in preference to ferries. The San Francisco connection is via the Bay Shore Highway. Traffic from the bridge to San Francisco would greatly increase congestion on this important highway.

It is believed that many years will elapse before traffic centers move far enough south to justify Location No. 5 as a major bay crossing. When such a time does arrive, the population of the bay area will have increased to such proportions that a bridge on any of the northern locations will be over-loaded. A bridge at Hunter Point does not meet the traffic needs of the bay cities at this time. It can only be considered as a location for the distant future expansion of bridge facilities when a centrally located crossing becomes overcrowded.

4. Relative studies as to the effects on navigation.

(a) *General.*

Referring to Traffic Survey, Section I-B, a survey of shipping with reference to its dock destination, is shown on Plate No. 36. A summation of results is as follows:

During the yearly period a total of 22,633 vessels with a net tonnage of 17,318,580 tons and a cargo tonnage of 7,403,531 tons, passed Location No. 3 to dock in San Francisco.

A total of 9887 vessels with a net tonnage of 11,954,563 tons and a cargo tonnage of 5,139,146 tons, passed Location No. 4 to dock in San Francisco.

A total of 8409 vessels with a net tonnage of 8,892,169 tons and a cargo tonnage of 3,699,776 tons passed Location No. 1-A.

A total of 8117 vessels with a net tonnage of 7,678,302 tons and a cargo tonnage of 3,337,423 tons passed Location No. 1.

In addition to the above figures, all the shipping to Oakland passed Locations Nos. 3 and 4. A study of these figures leads to the conclusion that Location No. 4 may be considered a lesser hindrance to navigation than Location No. 3.

(b) *Location No. 1.*

Location No. 1 with respect to commercial shipping may in the same light be considered a lesser hindrance than either of Locations Nos. 3 or 4. As docking facilities in San Francisco must develop toward the south, rather than north, this relative advantage of No. 1 will become smaller and smaller. Location No. 1 has an added disadvantage in that it crosses the naval anchorage. In this respect it must be considered a much greater hazard to naval maneuvers than are Location Nos. 3 or 4.

(c) *Comparison of Locations Nos. 3 and 4—Ferry traffic.*

The effect of Locations Nos. 3 and 4 on ferry traffic is as follows:
A total of 120 ferryboats pass Location No. 3 daily. They are:

Ferry Building to Sausalito	66
Ferry Building to Richmond	42
Ferry Building to Vallejo	12

These ferries will continue to operate after the bridge is built.

A total of 283 passenger ferry trips, 247 automobile ferry trips and 48 freight ferry trips pass Location No. 4 daily. A bridge carrying interurban passengers on Location No. 4 will eliminate all the passenger and automobile ferries now crossing Location No. 4, leaving only the freight ferries.

During the period of construction of a bridge on Location No. 4 it may be necessary to construct a temporary ferry terminal on the west side of Goat Island connected to Oakland by the bridge east of Goat Island and roads and tracks on the island. Such a terminal would be just north of the bridge on the island and would be required for a period of 1½ or 2 years. Piers Nos. 3 and 4 of the main channel structure would be constructed last. The period of operation of the temporary Goat Island terminal would start with the beginning of construction of these piers and continue until the completion of the bridge. The cost of such a terminal is estimated at $1,250,000. This cost has not been included in the estimate for Location No. 4 because of its doubtful necessity. Upon the completion of a bridge on Location No. 4, all ferries passing this location except as noted above will be eliminated.

It is thus shown that upon completion of a bridge there will be a total of 120 ferry trips past Location No. 3, and 48 ferry trips past Location No. 4. In this respect, Location No. 4 is superior to Location No. 3.

6. Summation of construction costs, operation and bond retirement.

Table No. 49 is a general summation of construction estimates, operation costs, bond retirements and reserves for maintenance after tolls are removed. This table shows:

First—Construction cost.

Second—Estimated property requirements.

Third—Initial annual cost of operation.

Fourth—Toll rates necessary to accomplish the respective bond redemption and reserve requirements.

Fifth—Percentage of total transbay traffic which it is estimated will be diverted to the bridge.

Sixth—Number of years required after the opening of the bridge to retire the bonds and establish a reserve for maintenance.

Seventh—Reserve accumulated in each case to be used for maintenance after the bonds are redeemed.

A study of Table No. 49 indicates that a structure on Location No. 4 will cost very much less than any of the other centrally located bridges and, as a result, can be paid for in a correspondingly shorter time, after which it will become a free bridge.

It would seem entirely feasible to reduce the present tolls on automobiles to 40 cents per car, instead of 60 cents as at present, and to reduce the truck and commodity tolls 20 per cent under the present tolls. On such a toll basis, the bridge can be paid for in approximately 20 years, with a reserve for maintenance of $11,500,000.

SECTION V

SUMMARY AND CONCLUSIONS

1. Summary.

The summary of the report is found on pages 158 to 163, inclusive, and reiterates to more or less degree the statements made in this brief.

2. Conclusions and recommendations.

A study of the data assembled in this report leads to the following conclusions:

First—The construction of a bay crossing to transport existing and future transbay traffic between San Francisco and East Bay cities is very necessary to the development of the bay and is entirely feasible from economic and construction viewpoints.

Second—The present and future traffic needs for many years to come require that such a crossing be located on a relatively direct line between the centers of automobile and commuter traffic and that it carry both automobile and interurban traffic.

Third—That the centers of automobile and commuter traffic, though moving slowly southward, will remain approximately in their present positions until such time as the proposed crossing is carrying its full capacity.

Fourth—That in consideration of conclusions 2 and 3, the proper locations to be considered at present are Location No. 1 (Rincon Hill-Alameda), Location No. 3 (Telegraph Hill-Key Route mole), Location No. 4 (Rincon Hill-Key Route mole), and the Tube Line.

Location No. 5 should only be considered for future bridge expansion when a crossing centrally located has become congested.

Fifth—That piers for all the heavy spans should be founded on the best possible material available. This is shale and sandstone.

Sixth—That the best possible traffic distribution centers for both highway and interurban traffic are necessary both in San Francisco and Oakland and should be built complete as part of the bridge project.

Seventh—That a structure capable of carrying the anticipated traffic must provide for six lanes of vehicular traffic and two operative interurban tracks with a third passing or emergency track.

Eighth—That the most economic structure for the traffic requirements is a double deck structure with six lanes of vehicular traffic on the upper deck and the required tracks on the lower deck.

Ninth—That the bridge must offer a minimum of interference to both naval and commercial navigation.

Tenth—A further conclusion is that a bridge constructed on Location No. 4, from Rincon Hill, via Goat Island, to the Key Route mole will best meet these requirements. Its selection is recommended for the following reasons:

(a) No other location offers a more direct connection between traffic centers.

(b) Location No. 4 is the only location on which shale or rock foundations can be obtained for all heavy piers within practical depths.

(c) The cost of a double deck structure on Location No. 4 is $7,250,000 less than on Location No. 3 and $23,000,000 less than the cheapest structure on Location No. 1, *i. e.*, Location No. 1-C.

(d) Location No. 4 connects the most desirable traffic distribution centers in San Francisco and Oakland.

(e) Location No. 4 is superior to Location No. 3 in its effect on navigation and Location No. 1 shows no advantage in this respect when naval interests are considered.

(f) On Location No. 4 the present rate of ferry tolls can be materially reduced and the bridge paid for in less than twenty years.

RECOMMENDATIONS

After careful study of all considerations involved, we recommend:

That Location No. 4, from the Rincon Hill District in San Francisco, via Goat Island, to Oakland over the Key Route mole be adopted.

That a double deck structure, with six traffic lanes on the upper deck and interurban tracks on the lower deck with proper terminal facilities be built.

That main channel spans 1700 feet long be used with 220 feet vertical clearance above low water and approximately 1600 feet horizontal clearance between pier fenders.

APPENDIX

The Appendix of the report includes:

1. Detailed logs of all borings.
2. Mechanical analysis of samples by consulting geologists.
3. Data on tides and currents in the San Francisco Bay.
4. Charts, maps and plans of the various locations studied and the structures proposed thereon.

PART C

SAN FRANCISCO BAY BRIDGE

REPORT TO

HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION

BY

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

JULY, 1930

HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION

Mark L. Requa, Chairman.
George T. Cameron, Vice Chairman.
Rear Admiral Luther E. Gregory, U. S. N.
Rear Admiral W. H. Standley, U. S. N.
Brigadier General G. B. Pillsbury, U. S. A.
Lieutenant Colonel E. L. Daley, U. S. A.
Senator Arthur H. Breed.
Charles D. Marx.
C. H. Purcell, Secretary.

Sacramento, July 19, 1930.

MR. B. B. MEEK, *Director,*
Department of Public Works,
Sacramento, California.

DEAR SIR:

We herewith submit a report on several proposed locations for a connection between San Francisco and Alameda counties.

This is in accordance with the resolution passed by the Hoover-Young San Francisco Bay Bridge Commission on October 7, 1929, which reads as follows:

> "*Resolved,* That the Department of Public Works of the State of California be asked to make an economic and traffic study and furnish the Commission with all data obtained for the purpose of determining the relative value of the several proposed locations for a connection between San Francisco and Alameda counties."

The subject matter of this report has been compiled by the Bridge Department of the Division of Highways under the direction of Chas. E. Andrew, bridge engineer. Traffic studies (Section I-A of the report), consisting of data on transbay passenger and automobile traffic between San Francisco and the East Bay, have been complied by Mr. Lester S. Ready, consulting engineer, of San Francisco.

The completion of a boring contract on June 26, 1930, consummated the exploration of foundation conditions on San Francisco Bay. In the report designs and preliminary estimates are presented for four locations and two alternatives. These are submitted in order that they may be readily available in the economic study which is considered necessary in the final determination of the feasibility of the project.

Very truly yours,

(Signed) C. H. PURCELL,
State Highway Engineer.

Sacramento, July 19, 1930.

To the Members of the Hoover-Young
San Francisco Bay Bridge Commission.

GENTLEMEN:

I am herewith transmitting the report of the Department of Public Works, Division of Highways, upon its investigation into the engineering and economic practicability of several proposed locations for a connection between San Francisco and Alameda counties.

The facts and findings in this report indicate that a crossing from San Francisco to the East Bay is feasible both from an engineering and an economic standpoint.

Respectfully submitted.

(Signed) B. B. MEEK,
Director.

REPORT BY THE DEPARTMENT OF PUBLIC WORKS, STATE OF CALIFORNIA, DIVISION OF HIGHWAYS, TO THE HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION.

INTRODUCTION

Pursuant to a resolution passed by the San Francisco Bay Bridge Commission on October 7, 1929, which reads:

"*Resolved,* That the Department of Public Works of the State of California be asked to make an economic and traffic study and furnish the Commission with all data obtained for the purpose of determining the relative value of the several proposed locations for a connection between San Francisco and Alameda counties," the following report is submitted.

This report consists of data collected by the Department of Public Works of the State of California, at the request of the Hoover-Young San Francisco Bay Bridge Commission, and follows in general the outline requested in the above resolution.

It consists: *first,* of a study of all transbay traffic which might be considered tributary to a bay crossing between San Francisco and the East Bay district; *second,* a general compilation of water-borne traffic and commerce on San Francisco Bay; *third,* a compilation of foundation data and discussion of same; *fourth,* an engineering study of possible locations; *fifth,* estimated revenues; *sixth,* recommendations.

ACKNOWLEDGMENTS

Acknowledgments and thanks are due to numerous individuals and public bodies for the material assistance and whole-hearted cooperation which has been rendered.

Credit is due the United States Engineers for the use of instruments, as well as information and maps.

Grateful acknowledgment is made the United States Navy Department and United States Coast and Geodetic Survey for the valuable information and maps which have been generously furnished.

The city engineer's office of San Francisco has kindly supplied us with various data including maps and records which they have prepared in the past on various proposed crossings. They have supplied us with copies of the 1927 report by Messrs. Ridgway, Talbot and Galloway. This report contains extensive and exhaustive data on the many phases of the problem. Therefore it seems hardly necessary to add further data on the matters of description, harbor, commerce, ships, and rail transportation. In the matter of traffic and income statistics it appears only necessary to correct the predicted statistics by inserting the actual and connecting the future predictions with the additional

information now at hand. Also by augmenting such data by any additional facts that may have become evident since the preparing of that report.

The 1927 report is full and complete, representing the best judgment of eminently capable engineers, based upon the information available at that time. It was of valuable assistance in the making of this report. We take the liberty of referring to the 1927 report, and the data which it contains.

We wish to express our gratitude to the Board of State Harbor Commissioners, the San Francisco and Oakland Harbor engineers, and the Chambers of Commerce of both San Francisco and Oakland for rendering material assistance in collecting data and records on navigation and shipping

Whole-hearted cooperation has been given by all members of the board of supervisors of the city and county of San Francisco. The city of San Francisco has, through its board of supervisors, supplied funds to the amount of $40,000 without which it would have been impossible to make this report.

The additional funds required have been supplied by the Bridge Authority created by the 1929 state legislature.

CONTENTS

Section I—Traffic Survey.

Section II—Borings and Foundation Data.

Section III—Design Data.

Section IV—Economic Studies.

Section V—Summary and Conclusions.

SECTION I

TRAFFIC SURVEY

I-A. Passenger and Automobile Traffic.

1. Phases of traffic study.

Five phases of transbay traffic as related to the location of a bridge between San Francisco and Alameda counties are dealt with herein:

(a) Origin and destination of present transbay passenger and vehicular traffic.

(b) Relative serviceability of different bridge locations as measured by distance and time required for transbay travel.

(c) Characteristics of traffic flow.

(d) Growth of transbay traffic (geographic and quantitative).

(e) Relative cost to transportation companies and to vehicular traffic of operating via the present ferries and the several bridge locations studied.

2. Present transportation facilities.

The present ferry service other than freight includes:

(a) Passenger Ferry Service:

Connection with electric train and main line service in East Bay:

	Ferry distance	*Daytime headway*
(1) Key System Transit Company:		
From Ferry Building, San Francisco, to Key Route Pier, serving generally Albany, Berkeley, Emeryville, Oakland, Piedmont and Sacramento Short Line	2.85 miles*	20 minutes
(2) Southern Pacific Company:		
Interurban and main line—		
From Ferry Building, San Francisco, to Oakland Mole, serving generally Albany, Berkeley, Emeryville, Oakland, San Leandro, and connecting with main line trains	3.50 miles*	20 minutes
(3) Southern Pacific Company:		
Interurban—		
From Ferry Building, San Francisco, to Alameda Mole, serving Alameda and part of East Oakland	3.00 miles*	30 minutes
(4) Santa Fe Main Line:		
From Ferry Building, San Francisco, to Ferry Point, Richmond, serving main line traffic only	7.80 miles	Train connections
(5) Western Pacific Main Line:		
From Ferry Building, San Francisco, to Western Pacific Mole, serving main line passengers only	3.64 miles	Train connections

* Distance from official time tables—other distances scaled.

NOTE.—For location of ferry routes and interurban lines see Plate 27.

(b) Vehicular Ferry Service (operated by Southern Pacific-Golden Gate Ferry Company, Limited:

	Ferry distance	*Daytime headway*
(1) Hyde street, San Francisco, to Berkeley Pier	4.40 miles	20 minutes
(2) North End Ferry Building, San Francisco, to Ferry, Point Richmond †	7.80 miles	40 minutes
(3) South End Ferry Building, San Francisco, to Oakland Mole (7th street, Oakland)	3.50 miles	10 to 15 minutes
(4) South End Ferry Building, San Francisco, to foot of Broadway, Oakland †	6.40 miles	90 to 120 minutes *
(5) Ferry Building, San Francisco, to Alameda Mole	3.30 miles	30 minutes

† Foot passengers handled on these ferries.
* Week-day service only.
NOTE.—For location of vehicular ferry routes, see Plate 27.

3. Proposed bridge locations.

Five bridge locations were given special consideration. The San Francisco terminals coincide in general with the four terminals listed in the San Francisco Bay Bridge Commission minutes of October 7, 1929. Two locations have their terminals at Rincon Hill.

Location 1—From Rincon Hill, San Francisco, to Alameda Mole, thence to Cedar and Peralta streets, Oakland.
(Designated as Location 1 by Board of Engineers, Transbay Bridge, San Francisco.)

Location 2—From Potrero Hill, San Francisco, to Pacific avenue, Alameda, and north to crossing of Oakland Estuary, as in (1).
(Designated as Location 2 by Board of Engineers.)

Location 3—From Telegraph Hill, San Francisco, to Goat Island, thence to Emeryville and Oakland, via Key Route Mole.
(Designated as Location 3 by Board of Engineers.)

Location 4—From Rincon Hill, San Francisco, to Goat Island, thence to Emeryville and Oakland, via Key Route Mole.

Location 5—From Hunter Point, San Francisco, to foot of Main street, Alameda, thence to Oakland.

NOTE—For general location of these bridges, see Plates 27 and 28.

4. Scope of investigation.

The investigations upon which this report is based are briefly described as follows:

First—A study was made of available reports on the subject of a transbay bridge, including that of the San Francisco Board of Engineers; the report to the Intercity Bridge Company; records with reference to traffic and operating costs of existing transportation companies, compiled by the engineering staff of the California Railroad Commission; and data from other sources, including reports listed on page 90.

Second—An origin and destination census of all passenger and vehicular traffic (other than main line passenger traffic) between San Francisco and the East Bay on a typical week-day was taken with the assistance and cooperation of the Railroad Commission's engineers and

the three ferry companies—Key System Transit Company, Southern Pacific Company and Southern Pacific-Golden Gate Ferry Company, Ltd. The data obtained were compiled in order to determine serviceability of various bridge locations.

Third—Analysis was made of available data pertaining to or affecting the growth of transbay traffic and a study of experience in connection with other bridges was made to determine an estimate of future growth of traffic.

Fourth—Costs of existing passenger ferry service were studied to ascertain possible revenue from interurban service operated across the bridge. Relative costs of operation of public carriers, buses and privately owned vehicles via the several bridge locations were analyzed.

No attempt has been made to lay out details of main arterial streets or terminal plazas to distribute vehicular bridge traffic. This is primarily a problem of design to follow the determination of traffic facts.

5. Cooperation.

Throughout the entire investigation we have received the full cooperation of various organizations and individuals. The engineering department of the California Railroad Commission has made available all pertinent records and has assisted materially in the survey. Consultations have been had from time to time with Mr. A. G. Mott, chief engineer, and Mr. J. G. Hunter, transportation engineer. Mr. Ward Hall, assistant engineer transportation division, who had heretofore handled similar surveys for the Commission, supervised the origin and destination survey. He has also assisted materially in the study of traffic routes and estimates of interurban train operation via the several bridge locations. Other engineers of the division have given their assistance and during the traffic survey the major part of the field force was drawn from this department.

The three transportation companies—Key System Transit Company, Southern Pacific Company and Southern Pacific-Golden Gate Ferry Company, Ltd.—cooperated in the traffic survey, making men available to assist wherever needed and arranging for distribution and collection of questionnaires.

Data were readily supplied by the Oakland Chamber of Commerce, the Major Highway and Traffic Committee of Oakland, the Traffic Survey Committee of San Francisco, and by Mr. Paul Ost of the city engineer's office, city of San Francisco. Other data pertaining to growth of communities were furnished by The Pacific Telephone and Telegraph Company. Reports were supplied by the Delaware River Bridge Joint Commission of Pennsylvania and New Jersey, and by Port of New York authorities on bridges and tunnels under their jurisdiction.

6. Origin and destination of traffic.

An important point in determining the most advisable location is the origin and destination of the traffic to be served. With this in view, a survey of interurban train and ferry passengers was made on Thursday, December 12, 1929, followed on Tuesday, December 17, 1929, by a vehicular traffic count. These particular days were chosen as giving facts typical of regular week-day traffic.

The data represent the major part of passenger traffic. Sunday and holiday automobile travel is greater than week-day travel but inasmuch as the greater part is for pleasure, the shortness or directness of route has not been considered important. Weight, however, should be given to the question of business travel.

Main line passenger service of the Southern Pacific, Western Pacific and Santa Fe railroads was not included in the origin and destination survey, the amount being relatively minor (approximately 4 per cent of the total). Toward San Francisco, the destination would be centrally located, while in the East Bay, it is fixed by terminal passenger stations.

(a) Interurban Train and Ferry Passengers.

(1) *Survey.*

The procedure followed in the survey was to obtain from each train passenger, through questionnaires, the points in San Francisco and the East Bay between which he was traveling. During the day of Thursday, December 12, 1929, eastbound passengers entering the San Francisco Ferry Building (traveling by Key System and Southern Pacific ferries to Oakland and Alameda) were handed cards which provided for notation of the nearest street intersections in San Francisco and the East Bay between which they were traveling. These cards carried the following questions:

Q. From where in San Francisco did you come?
   a. Nearest street intersection
      and
   b. Office building (if any).

Q. At what station will you leave the train?

Q. To where are you going?
   a. Nearest street intersection
      and
   b. City or town.

The cards were collected by conductors on the trains in the East Bay and filed in envelopes on which were noted the number of passengers in each car. These envelopes were then filed by runs and lines.

(2) *Analysis.*

San Francisco and the cities of the East Bay were divided into zones, as set forth on Plates 27 and 28. These zones were laid out after general study of each community with the idea of dividing the two districts into sufficient units to insure accurate determination of distribution of traffic and relative distances to the several bridge heads. In addition, zone numbers were assigned to the main arterial highways extending beyond San Francisco and the East Bay to account for traffic originating beyond the main areas.

The cards were run through an electric tabulating machine, which sorted and counted them as to zones. The number of passengers reporting was classified by zones and ferry runs. In view of the varying percentage of nonreporting passengers, the total number was prorated to the various zones in proportion to distribution of reporting

passengers on each line. By this means a more accurate distribution of traffic was obtained than if the study were based simply upon passengers reporting. Inasmuch as a large proportion of transbay traffic is "commuter," which might have a different distribution than average, a classification by zones of those passengers leaving the San Francisco Ferry Building from 4.20 p.m. to 6.20 p.m. was made (as shown in Table No. 1).

Table No. 1 shows the results of the survey and on Plate 27 is set forth all transbay interurban train and ferry passengers (not including vehicular ferry passengers), both in percentage of total and the total crossing the bay on December 12, 1929. The eastbound traffic on that date via the Key System Transit Company was 20,995; via Southern Pacific Oakland Ferry, 20,433; and via Southern Pacific Alameda Ferry, 6688; a total of 48,116 passengers.

It is to be noted that 68 per cent of the total travel to the East Bay area has its origin in Zones 1, 2, 3 and 4, the downtown business and commercial area of San Francisco. The geographic centers of origin and destination for San Francisco and the East Bay are designated on Plate 27.

(b) Vehicular Traffic.

(1) *Survey.*

The procedure for counting vehicular traffic was in general the same as for passengers except that travel both ways was considered and the cards filled out by Commission employees rather than by the drivers of vehicles. This survey was made on Tuesday, December 17, 1929, and the cards carried the following questionnaire:

(a) Classification: Truck, stage, automobile, motorcycle, team.
(b) Number of passengers.
(c) Origin and destination:
    a. City
    b. Nearest street intersection
    c. Main highway traveled for automobiles from beyond San Francisco and the East Bay area.

(2) *Analysis.*

These cards were coded by zones and tabulated in total and in per cent. Owing to incomplete data obtained in several instances, vehicles going to Oakland and not giving street intersections were arbitrarily assigned to Zone 52; those going to Berkeley were listed in Zone 62; and those to Alameda, in Zone 71. Where location was not given in San Francisco, vehicles were prorated in proportion to those giving destination. These zones in the East Bay were chosen as being neutral with reference to the various bridge locations. Distribution of vehicular traffic in San Francisco and the East Bay is set forth in Table No. 2 and Plate 28. The geographic centers of origin and destination on the two sides of the bay are designated on Plate 28. It should be noted that vehicles going beyond the city limits of San Francisco southward, or north of Richmond, or east of San Leandro in the East Bay, have been classified in special zones which include all traffic by main highways. The traffic for December 17, 1929, eastbound and westbound, totaled:

	Number	*Per cent*
Richmond Ferry	156	1.48
Berkeley	2,461	23.30
Seventh street, Oakland	7,532	71.00
Broadway, Oakland	46	0.44
Alameda	334	3.15
Totals	10,531	100.00

7. Relative serviceability of bridge locations.

In order to compare the relative serviceability from a traffic standpoint of the several bridge locations with the ferry service existing, a determination was made of the weighted average total travel distance and travel time for both interurban passenger and vehicular traffic via the present routes and the several proposed bridge locations. The first step taken was to lay out the five bridge locations (Plates 27 and 28).

(a) Travel Distance.

(1) *Interurban Passengers.*

In the case of interurban passenger service, loop systems or terminals for handling trains at San Francisco were laid out following in general the suggestions made in the report of the San Francisco Board of Engineers. In the East Bay, the bridges were considered as continuing toward a connection with existing interurban tracks. This procedure was followed not with the idea of designating the terminals of the bridge proper but in order to select that portion of transbay routes common to all passenger traffic.

The analyses herein are based on the assumption that interurban train service across the bridge would be operated on the San Francisco side at elevations above street grade, both in the loops and in the connecting lines to the bridge proper. Operation at street grade would congest traffic and unsatisfactory service would result.

Connection of interurban lines in the East Bay contemplates grade separations east and north on Locations 1 and 2, to cross Seventh street at Cedar, extending to the present viaduct at Tenth street; and to enter Seventh street at elevated or subgrades, extending east of Peralta street. On Locations 3 and 4, grade separations are contemplated east of San Pablo on Yerba Buena, to Fortieth street and Linden; east of Poplar street on Twenty-second, and on Poplar street to Seventh and beyond, across the estuary into Alameda. Connection of Alameda with Oakland is contemplated via bridge or tunnel. The connecting viaducts or subways are shown as dotted lines on Plate 27.

Table No. 3 sets forth general data with reference to bridge locations, loops and terminals for interurban passenger traffic. Table No. 4 gives similar data for vehicular traffic.

The approximate center of distribution for each zone was determined as designated on Plates 27 and 28. Thereafter a route of travel was laid out for interurban passengers from each zone via street car to the center of the loop system in San Francisco for Locations Nos. 1, 2, 4 and 5, and to the Ferry Building for present service and Location No. 3. Special routes were laid out for zones near the lines connecting the loops with bridge Locations Nos. 2 and 5. In the East Bay, routes followed the interurban lines to points designated as bridge terminals. No attempt was made to lay out each and every route traveled to or

from the transbay interurban system but such routes were selected as were considered typical or average.

The distance traveled via the chosen routes from each zone center to the Ferry Building was measured for present service and for Location No. 3, and to the center or average point of a loop with reference to Locations Nos. 1, 2, 4 and 5 in San Francisco (except as noted); also from zone centers to the various bridge terminals in the East Bay, where distance was allowed for pedestrian or street car travel from zone centers to interurban lines. Based upon these distances and the percentage of traffic from each zone, the weighted average distance traveled to each bridge terminal was computed for each side of the bay. To these distances were added the distances between the Ferry Building and the several East Bay ferry terminals for present service and across the various bridges for the respective locations.

(2) *Vehicular Traffic.*

The same procedure was followed for vehicular service. Routes were laid out from the zones to the bridge terminals for each location and to the various existing ferry terminals. Computations were made for all vehicular traffic to determine the weighted average travel distance between San Francisco and the East Bay.

Results for both passenger and vehicular traffic are set forth in Table No. 5.

(b) Travel Time.

The weighted average total travel times between points of origin and destination of passenger and vehicular traffic crossing the bay via the present service and the proposed bridge locations were determined, assuming in each case that all traffic now carried between San Francisco and East Bay by the ferries would be routed over the bridge.

(1) *Passenger Traffic.*

In determining travel time, speeds were assigned for travel across the bridge, on interurban and street car lines and for walking distances. In the downtown zones of San Francisco the total number of passengers was apportioned between pedestrians and street car patrons, based on general observation. Schedules now in effect were used for existing ferry service; also for interurban trains to the various ferries and proposed bridge terminals in the East Bay. Actual time schedules were applied to the street car lines in San Francisco and the East Bay. No waiting time was added for present interurban passenger ferry service at either the Ferry Building in San Francisco or at stations in the East Bay inasmuch as time intervals were identical. The rate of travel across the bridge has been assumed to average 30 miles per hour for interurban trains.

(2) *Vehicular Traffic.*

The San Francisco and East Bay districts were classified generally as to congested or noncongested areas, boulevard or nonboulevard streets, and average speeds of 10, 12½, 15 and 20 miles were assigned, based in part on consideration of results given in Dr. Miller McClintock's Report on the Street Traffic Control Problem of San Francisco, 1927. No attempt was made to test existing speeds by routes. Should the bridge be constructed, material changes in the street system lead-

ing to any of the bridge locations would be required. It should be noted that in comparing various bridge locations, the district in which accuracy of travel time is most important is largely limited to the relatively small areas between bridge terminals on each side of the bay. (Table No. 6 sets forth in general the speeds used.)

(3) *Results.*

Summaries are given in Table No. 5 showing weighted average time in minutes required under present service to travel from points of origin in San Francisco to points of destination in the East Bay via various bridge locations. Locations Nos. 1 and 4 appear to be equivalent in travel time. With the construction of the bridge at either location, interurban passengers will obtain an average saving of about 10 minutes; automobiles, about 29 minutes. Approximately 10 minutes of the latter represent average waiting and unloading time at ferry terminals.

In addition to the averages set forth in Table No. 5, Tables Nos. 7 and 8 have been prepared for passenger and vehicular traffic, showing the travel times and distances between certain points in the East Bay—Berkeley, Piedmont, Oakland and Alameda—and the center of origin in San Francisco.

8. Characteristics of traffic flow.

(a) Geographic Distribution.

Plates 29 to 34, inclusive, depict the flow of interurban passenger and vehicular traffic across the bay from the various zones via the present ferry systems and via Locations Nos. 1 and 4, as determined from the origin and destination survey. These plates have been prepared to visualize graphically the distribution of present traffic, assuming that the bridge would replace all ferry service. Exact street routes are not followed in the diagrams, the aim being to show only approximate distribution to the several zones.

Plate 29 shows passenger traffic via present routes. San Francisco traffic was not segregated between the several ferry lines as these all use the same terminal (Ferry Building).

Plate 30 is a diagram of passenger traffic routed via Location No. 1; Plate 31, via Location No. 4.

Plate 32 presents a diagram of present vehicular ferry service, segregation between the Berkeley-Hyde street ferry and the Oakland Seventh street ferry being made in the distribution of traffic on both sides of the bay. These ferries are operated at widely distant points on the bay front and the amount of traffic is sufficient in both instances to be indicated graphically. Plate 33 is a diagram of vehicular traffic via Location No. 1; Plate 34, via Location No. 4.

These diagrams are based on the assumption that with a bridge at either Location No. 1 or 4, all present ferry traffic would be routed thereon. Whether or not this would occur depends to a considerable extent upon a sufficient amount of traffic being retained by the ferries to justify continuance after completion of the bridge. It is possible that, with adequate bridges connecting Alameda, most of the traffic (except heavy trucking) would be diverted to the bridge via Locations Nos. 1, 3 and 4. Locations Nos. 2 and 5 would probably divert only

part of the traffic from the Richmond and Berkeley ferries. Location No. 5 in all probability would not divert interurban passenger service from either the Key System or Southern Pacific ferries and there would still remain considerable vehicular traffic using both the Berkeley and the Seventh street ferries.

(b) Time Distribution.

(1) *Passenger Traffic.*

The passenger traffic crossing the bay is maximum on week days and is influenced by "commuter" travel from the East Bay to San Francisco. It is largely westbound in the morning and eastbound in the afternoon.

Plate 2 sets forth Key System traffic on December 12, 1929, by ferry trips. This shows the typical distribution of passenger traffic crossing the bay throughout the day.

Plate 3 shows the hourly distribution of eastbound and westbound traffic for all passenger service as it occurred on December 12, 1929. As indicated on Plate 2, the traffic *peaks* between 5 and 6 p.m. eastbound and is materially higher than that for the full hour of 5 to 6 o'clock. Between 5.15 and 5.30 p.m. the traffic would be at a rate of approximately 25,000 passengers per hour.

(2) *Vehicular Traffic.*

Plate 4 depicts the variation in vehicular traffic across the bay on Tuesday, December 17, 1929. Plate 5 shows this variation by months for the year, and by days for the months of July and November, 1929.

The maximum hourly vehicular traffic for the year compared with the maximum monthly and annual vehicular traffic is as follows

	Total	*Vehicles Per 1,000,000 annual traffic*
Total traffic year 1929	4,490,513	1,000,000
Maximum month	424,875	94,616
Maximum day	23,341	5,198
Maximum hour	1,909	425

With the bridge in operation, it may be expected that a slightly greater *peaking* of travel will result than indicated, since the depression of peak day and maximum hour traffic occurs to a certain extent with ferry operation, owing to the requirement that automobiles await the necessary boats.

Analysis of experience with the Philadelphia-Camden Bridge and the Holland Tunnel (New York City) shows the following ratio of maximum daily and hourly traffic to annual traffic for 1929. During the year, the Philadelphia-Camden Bridge carried 11,615,609 vehicles and the Holland Tunnel, 10,977,910.

Vehicular Traffic per Million of Annual Traffic

	Philadelphia-Camden Bridge 1929	*Holland Tunnel 1929*	*S.F.-E.B. vehicular ferries 1929*	*Estimate S.F.-E.B. Bridge 1940*
Number of traffic lanes	6	4	----	----
Annual (units)	1,000,000	1,000,000	1,000,000	1,000,000
Maximum month	111,870	101,143	94,616	100,000
Maximum day	5,567	4,945	5,198	5,400
Maximum hour	630	355	425	500

The wide variation in maximum hourly traffic between the Philadelphia-Camden Bridge and the Holland Tunnel is in part due to the number of effective traffic lanes. The Holland Tunnel is limited to two lanes each way with a maximum of about 1200 cars per lane. The Philadelphia-Camden Bridge has six lanes so arranged that the number operating in one direction may be changed to meet traffic conditions. On the peak hour of 1929, four lanes were operated westbound and two eastbound. A peak of 7316 cars was handled, or an average of more than 1200 per lane. If delay is not experienced, the maximum hour travel per million of total would be expected to equal at least 500 cars.

(3) *Class of Vehicular Traffic.*

Classification of traffic between automobiles, buses and trucks, as of December 17, 1929, shows:

	Total	*Per cent*
Automobiles	9180	87.17
Buses	41	0.39
Trucks	1273	12.09
Motorcycles	13	0.12
Horsedrawn vehicles	24	0.23
Totals	10,531	100.00

A reasonable classification of total annual traffic via the bridge would be:

Automobiles	86 per cent
Trucks	13 per cent
Buses	1 per cent
Total	100 per cent

9. Geographic trend of growth.

(a) San Francisco.

Very little information is available as to past or future trend of geographical distribution of traffic in San Francisco although population studies made by Harland Bartholomew and Associates for San Francisco Traffic Survey Committee, indicate residental growth tending northward of Market street. It is apparent that development of office and commercial structures has a material influence upon destination of interuban passenger traffic from the East Bay. (Approximately 52 per cent of the total traffic is destined to and from Zones 1, 3 and 5.) The commercial and business centers are constantly growing more to the north of Market street than south. It may be expected that the destination of interurban passengers will continue to lie in the business areas centering in Zones 1, 2, 3 and 5.

Construction of the Golden Gate bridge will tend to increase vehicular traffic from the north. Offsetting this, however, industrial development in San Francisco must of necessity continue southward, owing to lack of expansion area to the north. Plate 35 (prepared by the Chief Engineer of the Railroad Commission in connection with other matters) shows the territory (elevation below 100 feet) generally available for industrial development extending toward San Mateo and beyond, its logical trend.

The main center of origin or destination of interurban passenger and vehicular traffic in San Francisco may be expected to continue near its present location.

(b) East Bay.

Data relative to the geographical trend of origin or destination of traffic in the East Bay are likewise somewhat limited but three fairly definite indications as to trend of growth are available. In 1925, the Railroad Commission made a survey (similar to that conducted on December 12, 1929) of the transbay interurban passenger traffic. Comparison of distribution of traffic in 1925 and 1929 indicates a tendency of the center to shift southward in the East Bay. Statistics furnished by the Oakland Chamber of Commerce on location of industries in the area from Richmond in the north to San Leandro in the south for the last six years indicate new industrial developments 60 per cent south and 40 per cent north of 18th street, Oakland. A commercial study carried on by The Pacific Telephone and Telegraph Company with reference to estimated station development in the East Bay area shows a somewhat similar trend. This study was so compiled that the estimated development could be divided into districts north and south of the main center of Oakland, with a fairly large area generally including the portion south of 40th street and west of Lake Merritt which might be considered neutral. This study also indicates development to the southward. Table No. 9 sets forth results of three observations above. Plate 35 (above referred to) also shows the predominance of areas suited to industrial development south and east of Oakland rather than north.

The main center of traffic destination or origin in the East Bay may be definitely considered as tending to shift southward although not at any great rate.

10. Growth of traffic.

Table No. 10 sets forth by years the San Francisco-East Bay passenger traffic via the ferry routes for the period 1915 to 1929, inclusive. Table No. 11 gives vehicular traffic by years and by ferry lines for the same period. Table No. 12 sets forth the number of passengers carried on vehicular ferries.

Future developments of traffic will depend upon the location of the bridge if constructed, tolls that may be charged, growth of communities, etc. The division of passenger traffic between interurban or bus service and privately owned vehicles will depend largely upon the same factors.

Data herein presented with reference to distance and time required to travel by the different bridge locations indicate that in all probability a bridge via Hunter Point (Location No. 5) would not carry interurban trains or divert all the vehicular traffic from existing ferries; nor could it develop as great an amount of traffic as a more northerly route.

In the estimates included herein, consideration has been given primarily to traffic possible under (1) existing ferry service as it may develop, and (2) construction of the bridge, using one of three locations: No. 1, 3 or 4.

Several estimates of transbay traffic have been prepared. Mr. H. G. Butler, in reporting to the Intercity Bridge Company (1926) made a forecast of traffic from 1926 to 1940. At that time the Golden Gate Ferry Service (Hyde Street-Berkeley) was not in operation and its

effects could not be definitely calculated. Reduction of rates for vehicular ferry service made effective early in 1926 had also caused a marked change, not fully apparent at that time. The San Francisco Board of Engineers in 1927 made a revised estimate of transbay traffic, giving special consideration to Mr. Butler's report and facts developing subsequently. The Board's report is somewhat less optimistic and both estimates show less vehicular traffic for 1929 than was actually experienced. On the other hand, both reports appear too optimistic as regards passenger traffic in light of experience of the past four years.

Tables Nos. 10 and 12 indicate a shifting of traffic from interurban passenger service to vehicular, a decline of approximately 10 per cent appearing since 1925 in the number of passengers handled by the Southern Pacific and Key System passenger ferries with a very marked increase in the number carried on vehicular ferries.

The probable effect of bridge operation upon vehicular traffic and the deflection of travel from interurban to vehicular passenger service can only be approximated.

Previous reports have been studied and the actual experience of the last fifteen years analyzed. With these analyses as a background, Tables Nos. 13 and 14, together with Plates 6 and 7 were prepared, setting forth the actual and estimated passenger and vehicular traffic between San Francisco and the East Bay from 1915 to 1940. The population estimated by Mr. Butler has been used. Reference to Plate 7 shows the variation of unit traffic. The year 1915 was abnormal owing to the Panama Pacific Exposition in San Francisco. The marked increase in vehicular transbay traffic per capita and per car registration commencing in 1926 is largely accounted for by a 40 per cent reduction of automobile ferry rates effective July 13, 1925 (held up by court injunction until the first part of 1926), and to the installation of the Berkeley-Hyde street ferry service, June, 1927. There was also an increase of about 16 per cent in transbay one-way passenger rates, beginning in January, 1926. The effect of these changes is evident in the dropping off of rail passenger travel and its deflection to the automobile ferries. The steadily decreasing number of "passengers per vehicle" is due partly to the lessening number of foot passengers carried on vehicular ferries and the continued increase in general use of ferries during the weekdays when passengers average approximately two per vehicle.

It is apparent that reductions in automobile tolls and/or increase in service always have a tendency to deflect passenger traffic from train service.

Development of transbay vehicular traffic by ferries will be in part limited by terminal facilities in San Francisco and the resulting congestion of boat movements near the present Ferry Building. In estimating future traffic it is assumed that added slip facilities will be available pending construction of the bridge.

Placing the bridge on any of the central locations will result in a marked shortening of travel time via automobile and should have much the same effect on travel that improvement of service and rate reduction had in 1926. A shortening of the time by 25 to 30 minutes may be expected. Reduction of time for passenger service averages only 10 minutes. Increased vehicular traffic and deflection of passengers from interurban trains may be expected.

Experience with bridges between other important metropolitan areas shows that bridge development has a marked effect upon vehicular traffic. Across the Delaware River at Philadelphia, prior to construction of the Philadelphia-Camden Bridge, traffic had been handled by ferries. Upon completion of the bridge, the ferries lost about 60 per cent of their business while the bridge developed traffic equivalent to 110 per cent of the ferry traffic existing prior thereto. The increase has been quite marked ever since. A graphical comparison of the growth of vehicular traffic across the Delaware River is shown on Plate 8.

The estimates herein set forth differ quite materially from those presented by the San Francisco Board of Engineers. Total vehicular traffic has been estimated higher and passenger traffic, lower. Comparison of actual transbay traffic for 1929 with previous estimates, and with estimates for 1940, is shown in the following table:

Comparison of Estimates of Transbay Traffic

	H. G. Butler higher estimate 1926	*Board of Engineers San Francisco 1927*	*Actual and present estimate*
Automobile traffic, 1929	3,960,000	3,537,565	4,490,513*
Automobile traffic, 1940	10,150,000	6,958,300	10,824,000
Automobile passengers, 1929	9,225,000	8,243,000	10,174,028*
Automobile passengers, 1940	22,330,000	15,308,000	22,081,000
Train passengers, 1929	(No	38,701,000	35,923,855*
Train passengers, 1940	estimate)	45,792,000	36,759,000
Total passengers: Total traffic:			
1929		46,944,000	46,097,883*
1940		61,100,000	58,840,000

* Actual.

Tables Nos. 13 and 14 indicate estimated traffic assuming ferry service only; also with the bridge completed by 1937. The effect of completion of the bridge has been estimated as setting up a 20 per cent increase in vehicular traffic with a reduction of train passenger traffic equal to one-half the increased number of vehicular passengers. It is not believed that any material increase in the total passenger movement across the bay will result.

Previous reports have assumed a 25 to 30 per cent stimulation of vehicular traffic and a 10 per cent increase in the number of train passengers following completion of the bridge. The effect may be as great as this upon vehicular traffic but an increase in train passenger traffic can not be expected.

11. Probable revenue.

Two main sources of revenue are available to the bridge, assuming that it handles both automobile and interurban train traffic:

(1) Tolls for automobile travel.
(2) Rental or toll for use by interurban trains.

(a) *Automobile Toll Revenue.*

The main items of present rates for ferry service across the bay include:

(1) Vehicles:

Automobiles	$0 60
Trucks—2 tons or less	75
2–4 tons	1 25
Over 4 tons	1 40
Buses	1 40

(2) Passengers:

Charge in addition to above 5 cents per person.

(3) Commodities:

Charge in addition to above truck charges, from 7 cents to 14 cents per 100 pounds.

Toll charges for the Philadelphia-Camden Bridge and the Holland Tunnel include no passenger or commodity charges and this practice may be followed on the Hudson River Bridge. The rates for the former are as follows:

	Philadelphia-Camden Bridge *	*Holland Tunnel*
Automobiles (pleasure cars, etc.)	$0 25	$0 50
Small trucks up to 2 tons	25	50
ø Trucks: 2–5 tons	40	75
5–10 tons	50	1 00
10–12 tons	65	special
Buses: Single deck	60	1 00
Double deck	75	----

* Solid tired vehicles are charged 10 cents more than pneumatic.
ø Trucks classified on basis of gross weight fairly equivalent to capacity listed.

The rates charged on the San Francisco Bay bridge would be influenced by the difference in cost and saving of time experienced, as compared with present ferry service. Analysis of the cost of operating automobiles, trucks and buses indicates that on good highways the running expense (exclusive of operators' wages, interest, insurance, etc.), is approximately 4 cents per mile for the average automobile, 12 cents for trucks and 10 cents for interurban buses. On this basis, together with the estimated vehicular traffic for 1940, the additional cost per car trip and the total annual cost are computed (Table No. 16).

Offsetting the added cost of 20.3 cents to 22.5 cents per car trip for Locations Nos. 1 and 4, over present ferry service, there is an average saving of at least 26 minutes. The value of this element of time saved is quite intangible and has not been estimated. Without question however, it is considerable and would offset the added cost of operation, having a definite tendency to encourage traffic even with the rates as now in effect on the ferries.

The table also indicates the added cost of operating via Location No. 5 compared with Locations Nos. 1 and 4. Location No. 5 shows an added cost of 26.6 cents per car trip over Location No. 1; also an added average travel time of 15.6 minutes. The added travel cost applied to the total trips estimated for 1940 represents approximately $2,900,000, to which would be additive the value of the additional time required. Tables Nos. 5 and 16 are based on averages.

The probable revenue from vehicular traffic across the San Francisco Bay bridge based on estimated traffic for 1940 may be approximated by applying the present schedule of rates, both with and without passenger and commodity charge. In the following table an estimate has been made, based on the assumptions (1) that all traffic is diverted to the bridge, and (2) that 8,000,000 car trips are diverted:

Estimated Annual Revenue From Vehicular Traffic 1940

	Total traffic via bridge			*8,000,000 vehicles via bridge*		
(a) Present schedule of rates without passenger or commodity charges:	*Units*	*Rate*	*Revenue*	*Units*	*Rate*	*Revenue*
1. Automobiles	9,417,000	$0 60	$5,650,200	6,960,000	$0 60	$4,176,000
2. Trucks	1,299,000	1 00*	1,299,000	960,000	1 00	960,000
3. Buses	108,000	1 40	151,200	80,000	1 40	112,000
Totals	10,824,000		$7,100,400	8,000,000		$5,248,000
(b) Passenger rate 5 cents	22,081,000	$0 05	1,104,050	16,000,000	$0 05	800,000
Totals			$8,204,450			$6,048,000
(c) Commodity revenue at present average rate, assuming freight growth proportional to total traffic growth			600,000			440,000
Totals based on present rates			$8,804,450			$6,488,000

* Estimated average charge exclusive of commodity charge.

(b) *Revenue from Interurban Train Service.*

Present interurban service is rendered by two carriers—Key System Transit Company and Southern Pacific Company—and by three ferry lines (as designated on Plate 27).

Completion of the bridge and transfer of interurban train traffic thereto would make nonoperative a large part of the present capital, including boats, slips, portions of the terminal facilities, and several miles of track. Replacement of a considerable number of cars would be necessary on account of different types and voltages now being used.

For several years the operations have not been considered profitable, and, as indicated heretofore, there has been a definite, material decline in traffic since 1925.

Major construction required in addition to the San Francisco loop or terminal and the bridge proper, to connect the present system in the East Bay with the bridge, either on Locations Nos. 3 and 4, or Locations Nos. 1 and 2, is indicated on Plate 27.

To determine the possible revenue which might accrue to the bridge under present rates and traffic, operations of the Key System Transit Company and Southern Pacific Company interurban train and ferry service for the past several years were analyzed. Operating and maintenance costs pertaining to ferries and structures not required for operation via the bridge were eliminated. Other items were determined on unit cost per revenue car mile or equivalent single track mile, as appeared most logical. The total car mileage via the several bridge locations was estimated for a coordinated or unified system. The cost of operating the remaining trackage plus cost of operating total equipment required was determined for the different locations on the basis of either cost per track or car mile.

In the study, the following basic assumptions have been used:

(1) Total capital costs of bridge, San Francisco loop or terminal, together with track and overhead structure, plus cost of connecting present East Bay interurban train systems with bridge, have been considered as part of the cost of the bridge project to be compensated for in resulting average savings or increased rates.

(2) The cars used by the Southern Pacific Company are all-steel with four motors per car, operating at 1200 volts. The Key System uses both steel and wooden cars, some of which are equipped with but two motors, all of them operating at 600 volts. It has been assumed that Key System cars would be replaced by equipment of the general type recently purchased by the Northwestern Pacific Company for service in Marin County. These cars are of all-steel construction and have a seating capacity of one hundred. Any additional cars required would be of this type.

(3) Electric power required has been estimated as purchasable at present rates effective on the Key System.

(4) Train service equivalent to the present 20 to 40 minute schedule for Oakland and north, and the 30 to 60 minute schedule for Alameda, is assumed.

Table No. 17 presents a comparison of 1929 operations with estimated operating costs for the same amount of traffic exclusive of interest on cost of new railroads and bridge terminal structures, loop and approaches, and rental for use of the bridge, loop and approaches. This

setup has been used as there is not yet available an estimate of the cost of these structures. Line 12 of this table indicates the amount of revenue based on 1929 traffic and rates available after deducting operating and added equipment costs to pay a return on the remaining use and useful property of the carriers and on the cost of the bridge loop or approaches.

It is to be noted that with elimination of duplication under present ferry operation, the combined earnings for 1929 available for return on capital are $375,792, or 7 per cent on $5,368,600. The rate bases for the two systems under present operation exceeds $25,000,000. With the bridge constructed, a relatively large portion of the capital will become nonoperative. That still remaining operative will materially exceed $5,368,600.

Based on leaving the carriers (combined) with a net equipment to the 1929 earnings, after eliminating duplication, the balance available for return, or rental of bridge, loop and approaches, would be:

For Location No. 1	$897,230	Equivalent to return for interest, depreciation and maintenance, of 7% on $12,817,600
For Location No. 2	422,870	6,041,000
For Location No. 3	780,640	11,152,000
For Location No. 4	762,450	10,892,100
For Location No. 5	(deficit)	

The estimated interurban passenger and Southern Pacific main line traffic for 1940 is only slightly greater than the actual traffic for 1929 (see column 10, Table No. 13). With existing rates and the estimated traffic for 1940, the net available, were the bridge constructed on Location No. 1, would not exceed $1,000,000; on Location No. 4, not over $900,000.

(c) *Estimated Total Revenue.*

The estimated total gross revenue available to cover operating costs and fixed charges on bridge, loop terminals and approaches, for the year 1940, based on present rates and with bridge at Location No. 1 or No. 4, and on the assumptions heretofore made as to proportion of automobile traffic diverted to the bridge, may be summarized as follows:

	Diversion of all vehicular traffic to bridge	*Diversion of 8,000,000 vehicles to bridge*
Revenue from vehicular traffic	$8,804,450	$6,488,000
Revenue from trains	900,000	900,000
Totals	$9,704,450	$7,388,000

(d) *Estimated traffic and revenue to be obtained by bridge via Location No. 5.*

The traffic to be expected over a bridge along Location No. 5 will be limited to automobiles. Interurban train operation can not be contemplated or expected via this location. This is apparent from consideration of the data shown in Table No. 5, which indicates for inter-

urban traffic that the average distance traveled would be 17.810 miles compared with present distance of 11.044 miles and that the travel time would be 62.832 minutes compared with the present of 58.477. Table No. 17 indicates that for Location No. 5, the added cost would be so great that there would be no money available from interurban passenger service to pay interest, depreciation or maintenance of the bridge, connecting lines or terminal facilities for this service.

Estimating the amount of vehicular traffic diverted from ferry service or developed by bridge at Location No. 5 must be at best only a general approximation. The engineering features and traffic data with reference to origin and destination of traffic, relative distance traveled and time saved have been definitely determined and are set forth elsewhere in this Section. Factors of attitude of automobile drivers to the relative value of time saved versus additional travel distance and driving distance with the resultant greater operating cost must also be given consideration, and as regards these elements there appears to be no great amount of experience to support any conclusions.

Table No. 8 sets forth for six typical points in the East Bay the relative average travel distance and travel time from these points to the traffic center of San Francisco for the present ferry routes and the various bridge locations.

From Table No. 2 and Table No. 8 have been compiled Table No. 24, entitled "Analysis of Transbay Vehicular Traffic," to show the amount of traffic originating in the various areas having the same general distance and time characteristics as indicated by the six points used in Table No. 8. Column (1) sets forth the zones in each group, column (2), the percentage of the total traffic originating in the zone and group, column (3), the added distance to be traveled by automobiles from the group area to the center of traffic in San Francisco, and column (4), the added driving distance in miles. The difference between amounts in columns (3) and (4) represents the distance traveled on ferry boats. Column (5) gives the estimated saving in travel time via Location No. 5 over the present ferry service. This is computed for the average automobile and not for trucks.

It is to be noted that for Group A, representing 14.24 per cent, of the vehicular traffic, Location No. 5 would entail driving 12 miles further at a loss of time. Group B, representing 14.19 per cent, would on the average save $4\frac{1}{4}$ minutes but would require driving approximately 10 miles further. Automobiles from Group C, representing 15.3 per cent, would be required to drive 9.71 miles further to save an average of 8.56 minutes. Automobiles from Group D, the center of Oakland, representing 36.21 per cent, would save 11.36 minutes but would have to travel 9.3 miles further. Group E shows approximately the same as for Group D; however, were a bridge constructed via Location No. 5, routing through Alameda might be expected which would result in somewhat greater saving in time and shorter travel distance. Alameda, listed under Group F, shows a saving of about 18 minutes with an added driving distance of 6 miles. Column (6) sets forth the average additional automobile operating cost per trip at 4 cents per mile.

The above discussion, together with Table No. 24, indicates average travel time and distance to the center of traffic in San Francisco. In

considering the possible division of use between a bridge and a ferry, it must be kept in mind that as to most trucks the speed of travel over a bridge with fairly heavy grades would be less than the average for automobiles and the cost of operation more per mile. It may be expected that the major portion of truck operation would find ferries more advantageous than the bridge, owing mainly to the lesser saving in time than indicated in Table No. 24 and the expense of driving approximately 10 miles per trip further. Time saved would be practically nil, while the added operating cost would be approximately $1 per trip.

Study of Plate 28 indicates that traffic between East Bay zones and the southern part of San Francisco will have a shorter distance to travel and a consequent greater saving in time than the average shown in Table No. 24. Table No. 25 has been prepared to show the proportionate traffic in the southern portion of San Francisco which might be considered as advantageously served by Location No. 5. Group X, totaling 80.15 per cent of the traffic, covers the northern portion of the city, and Group Y, totaling 19.85 per cent of the traffic, would in certain respects be served by a bridge via Location No. 5 as well as, or even better than, by present ferries.

Analysis of Tables Nos. 24 and 25, together with study of the general layout as indicated by Plate 28, have been made with a view to determining what percentage might continue by existing ferry routes. It is apparent that with a bridge via Location No. 5 requiring a travel distance from 5 to over 7 miles longer than by present ferry routes, and an added driving distance averaging about 10 miles, the ferry service would be expected to continue by the Richmond, Berkeley and Seventh street ferries. The Oakland-Broadway routes and the Alameda pier route probably would not be continued. From ferry route standpoint, it would appear that a bridge via Location No. 5 would have little if any effect on the traffic via Richmond and Berkeley ferries which handle 1.48 per cent and 23.3 per cent of the traffic respectively. The 71 per cent handled by Oakland ferry would lose possibly from 40 to 50 per cent, as an average saving of 11 minutes could be expected. On this basis, between 67 and 60 per cent would remain with the ferries and 33 to 40 per cent would go via the bridge.

A study of Plate 28 indicates that a bridge route by Location No. 5 would give sufficient saving in time so that practically all of the traffic to the entire city of San Francisco from East Bay groups, E and F, would be as well served by the bridge as by ferry. For the balance of traffic from East Bay, that destined to Group Y in San Francisco would save an additional 10 to 12 minutes over that shown in Table No. 26. This would tend to divert more traffic via Location No. 5. On the basis of all traffic from East Bay Groups E and F, and 20 per cent from the balance of East Bay going via the bridge, a total of 36 per cent might be diverted.

The following estimate has been prepared, based on consideration of each East Bay group separately, it being estimated that 10 per cent of the 12 per cent of total vehicles estimated as trucks would continue

operation by ferries owing to lack of time saved and increased cost of operation.

East Bay	*Bridge*	*Ferry*
Group A: 14.24% of traffic.		
Average time saved by bridge, .35 minutes.		
From this group the possible time saved except for the few cars to south of San Francisco would not appear to justify use of Bridge.		
Ferries:		14.24%
Group B: 14.19% of traffic.		
Average time saved by bridge, 4.25 minutes.		
Of these, approximately 20% destined to Group Y would save an addition of from 10 to 12 minutes average with a lesser differential in travel distance of 3 miles.		
Ferries: 10% trucks—72% automobiles		11.63%
Bridge: 18%.	2.56%	
Group C: 15.30% of traffic.		
Average time saved by bridge, 8.56 minutes.		
Of this group, 20% destined to Group Y would save an average of from 10 to 12 minutes additional, bringing saving to 18 to 20 minutes with driving distance of about 6.7 miles greater than by ferry.		
Ferries: 10% trucks—70% automobiles		12.24%
Bridge: 20%	3.06%	
Group D: 36.21% of traffic.		
Average time saved by bridge 11.36 minutes.		
Portion to Group Y would save 20 or more minutes with driving distance of 6.3 miles greater. Considerable use of bridge to northern San Francisco would be expected.		
Ferries: 10% trucks—45% automobiles		19.92%
Bridge: 45%	16.29%	
Group E: 15.67% of traffic.		
By routing through Alameda, practically all but trucks should travel by Bridge.		
Trucks via Ferries:		1.57%
Automobiles via Bridge:	14.10%	
Group F: 4.39% of traffic.		
All via Bridge owing to material saving in time.	4.39%	
Totals	40.40%	59.60%

Assuming equal fares or tolls by ferry and by bridge it would be our general conclusion that of the ferry traffic existing at the completion of the bridge, not to exceed 40 per cent of the traffic would be diverted by a bridge via Location No. 5. The bridge would develop some additional traffic, as would a bridge located by the more direct routes. On the basis of an increase of 20 per cent to cover development of business, the traffic via Location No. 5 for the year 1940, used as the basis for estimates in Sec. I would be 4,379,600 vehicles. The following is our best judgment as to the probable revenue to be received from a bridge at Location No. 5, on the basis of 1940 conditions and present tolls:

Item	Units	Rate	Revenue
(a) Present schedule of rates without passenger or commodity charge:			
1. Automobiles	4,248,200	$0.60	$2,548,920
2. Trucks and buses	131,400	1.00	131,400
Totals	4,379,600		$2,680,320
(b) Passenger.			
Rate of 5 cents	8,759,200	$0.05	$437,960
Total			$3,118,280
(c) Commodity			40,000
Grand total			$3,158,280

For reasons herein set forth, it may be contemplated that ferries would continue primarily for truck service even with a centrally located bridge so that the lower estimate, page 58, based on 8,000,000 vehicles, although not directly reflecting this fact, would be the more directly comparable.

TABLE No. 1. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Distribution on December 12, 1929, of Transbay Interurban Passengers by Zones of Origin in San Francisco and Zones of Destination in East Bay—Key System Transit Company and Southern Pacific Company, Combined

Zone number	San Francisco—Origin				Zone number	East Bay—Destination			
	4:40 p.m.–6:20 p.m.		Entire operating day			4:40 p.m.–6:20 p.m.		Entire operating day	
	Number of passengers	Per cent of total	Number of passengers	Per cent of total		Number of passengers	Per cent of total	Number of passengers	Per cent of total
1	9,232	38.00	13,419	28.56	50	10	0.04	42	0.09
2	2,928	12.05	4,029	8.58	51	333	1.36	927	1.93
3	5,963	24.54	12,406	26.41	52	1,139	4.65	5,002	10.39
4	1,473	6.06	2,090	4.45	53	278	1.14	1,866	3.88
5	1,094	4.50	3,152	6.71	54	1,279	5.23	2,367	4.92
6	964	3.97	1,776	3.78	55	1,133	4.63	2,189	4.55
7	276	1.14	438	.93	56	633	2.59	1,041	2.16
8	212	.87	917	1.95	57	1,290	5.27	2,269	4.72
9	58	.24	385	.82	58	233	.95	472	.98
10	273	1.12	1,358	2.89	59	79	.32	796	1.65
11	233	.96	1,297	2.76	60	2,189	8.95	3,479	7.23
12	639	2.63	1,934	4.12	61	121	.49	185	.38
13	302	1.24	469	1.00	62	2,750	11.24	5,316	11.05
14	98	.40	166	.35	63	548	2.24	1,226	2.55
15	35	.14	152	.32	64	254	1.04	483	1.00
16	28	.11	276	.59	65	783	3.20	1,224	2.54
17	13	.05	177	.38	66	7	.03	308	.64
18	76	.31	369	.79	67	1,447	5.91	2,293	4.77
19	80	.33	538	1.14	68	606	2.48	918	1.91
20	32	.13	80	.17	69	707	2.89	1,111	2.31
21	56	.23	523	1.11	70	54	.22	67	.14
22	3	.01	8	.02	71	1,194	4.88	1,978	4.11
23	19	.08	115	.24	72	599	2.45	1,163	2.42
24	6	.02	73	.16	73	520	2.13	869	1.81
25	21	.09	132	.28	74	950	3.88	1,356	2.82
26	12	.05	110	.23	75	597	2.44	1,017	2.11
27	0	.00	0	.00	76	258	1.05	444	.92
28	144	.59	484	1.03	77	1,487	6.08	2,695	5.60
46	12	.05	19	.04	78	1,061	4.34	1,495	3.11
47	9	.04	48	.10	79	4	.02	8	.02
48	12	.05	41	.09	80	0	.00	8	.02
49	0	.00	0	.00	81	1,108	4.53	1,830	3.80
					82	363	1.48	669	1.39
Totals	24,303	100.00	46,981	100.00	83	277	1.13	468	.97
					84	39	.16	123	.25
					85	44	.18	110	.23
					96	2	.01	13	.03
					97	5	.02	18	.04
					98	9	.04	40	.08
					100	76	.31	231	.48
					Totals	24,466	100.00	48,116	100.00

TABLE No. 2. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Distribution on December 17, 1929, of Transbay Vehicular Traffic by Zones of Origin and Destination in San Francisco and East Bay.—East and Westbound Combined

Zone number	San Francisco		Zone number	East Bay	
	Vehicles			Vehicles	
	Number	Per cent of total		Number	Per cent of total
1	963	9.14	50	36	.34
2	600	5.70	51	137	1.30
3	2,545	24.17	52	2,565	24.36
4	715	6.79	53	613	5.82
5	1,440	13.67	54	155	1.47
6	342	3.25	55	240	2.28
7	92	.87	56	235	2.23
8	347	3.30	57	262	2.49
9	248	2.35	58	84	.80
10	475	4.51	59	173	1.64
11	351	3.33	60	304	2.89
12	610	5.79	61	34	.32
13	76	.72	62	847	8.04
14	54	.51	63	97	.92
15	44	.42	64	191	1.81
16	95	.90	65	100	.95
17	60	.57	66	130	1.23
18	91	.87	67	267	2.54
19	241	2.29	68	151	1.43
20	60	.57	69	75	.71
21	340	3.23	70	27	.26
22	22	.21	71	198	1.88
23	76	.72	72	191	1.81
24	21	.20	73	143	1.36
25	69	.66	74	160	1.52
26	82	.78	75	297	2.82
27	2	.02	76	66	.63
28	33	.31	77	227	2.16
46	221	2.10	78	94	.90
47	26	.25	79	2	.02
48	171	1.62	80	13	.12
49	19	.18	81	122	1.16
			82	92	.87
Totals	10,531	100.00	83	113	1.07
			84		
			85	201	1.91
			96	1,006	9.55
			97	696	6.61
			98	187	1.78
			Totals	10,531	100.00

TABLE No. 3. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Location of San Francisco Terminals and East Bay Connections, Passenger Service

Location number	San Francisco terminal	Bridge location	East Bay terminal
1	Loop: Fremont-Bryant-Tehama Tehama-Fremont-7th 7th-Tehama-Bryant Bryant-7th-Fremont Length of loop; 2.60 miles	Rincon Hill at Fremont and Bryant to Alameda Mole; thence to 7th and Cedar, Oakland, with branch to present Alameda Electric Line. Loop to 7th and Cedar, 5.54 miles	7th and Cedar for Oakland and north; point west of Estuary crossing for Alameda.
2	Loop: Townsend-7th-Beale Beale-Townsend-Tehama Tehama-Beale-7th 7th-Tehama-Townsend Length of loop: 3.31 miles	7th and Townsend via 7th; R. of W. to foot of 22d; thence to a point south of Alameda Mole; thence North to and across Estuary to 7th and Cedar, Oakland; with branch to Alameda opposite west end of Pacific avenue. Tracks to bridge: 1.60 miles Bridge to 7th and Cedar: 6.01 miles Bridge to Main and Pacific: 5.16 miles	7th and Cedar for Oakland and north; at Main and Pacific streets for Alameda.
3	This terminal as noted on Map, follows that recommendation by Board of Engineers, for a point north of Ferry Building up around Telegraph Hill to bridge. Length of terminal to bridge: 1.57 miles	Telegraph Hill to Goat Island thence to Key Route Mole; thence via Key Route fill to Yerba Buena and Helen streets, Oakland; with a branch to 22d and Peralta streets. Length of bridge: 6.38 miles	At Yerba Buena and Helen sts. for north; 22d and Peralta streets for Central Oakland and Alameda.
4	Loop: Same loop as for location 1, except connecting at Harrison and Fremont streets. Length of loop: 2.69 miles	Rincon Hill, Harrison and Fremont to Goat Island; thence to Key Route Mole; thence via Key Route fill to same terminals as location number 3. Length of bridge: 6.69 miles	At Yerba Buena and Helen sts. for north; 22d and Peralta streets for Central Oakland and Alameda.
5	Loop: Same loop as for location 1, except connecting at 7th and Bryant streets. Length of loop: 2.69 miles	7th and Bryant via Vermont and Jerrold to Hunters Point; thence to a point south of Alameda; thence north to Main and Pacific. Tracks to bridge: 4.90 miles Bridge to Main and Pacific: 5.36 miles Main and Pacific to 7th and Poplar: 1.96 miles	At Main and Pacific streets for Oakland and north and Lincoln avenue Line; at Main and Central avenue for Encinal avenue line.

TABLE No. 4. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Location of San Francisco and East Bay Terminals—Vehicular Traffic

For vehicular service, bridge terminals were chosen for distance measurement purposes mainly, no attempt being made to determine or lay out adequate terminal facilities. This table sets forth pertinent data as to location.

Bridge location number	San Francisco terminal	East Bay terminal	Length between terminals, miles
1	At 2d and Harrison sts.	For Oakland and northb: At 7th and Peralta sts., Oakland	5.90
		For Alameda: At point on Alameda Mole fill west of estuary crossing	4.41
2	On 3d st., between 22d and 23d sts.	For Oakland and northb: At 7th and Peralta sts., Oakland	6.45
		For Alameda: At Main and Pacific sts., Alameda	5.56
3	On Green st. near Columbus ave.	For the north: At Yerba Buena and Helen sts., Oakland	7.08
		For Central and East Oakland and Alameda: At 22d and Peralta sts., Oakland	7.08
4	At 2d and Harrison sts.	For the northb: At Yerba Buena and Helen sts., Oakland	6.94
		For Central and East Oakland and Alameda: At 22d and Peralta sts., Oakland	6.94
5	At Jerrold and Mendell sts.	For Oakland and northb: At 7th and Adeline sts., Oakland	9.22
		For Alameda: At Main and Pacific sts., Alameda	7.31

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TABLE No. 5. SAN FRANCISCO BAY BRIDGE TRAFFIC SURVEY. FINAL SUMMARY—INTERURBAN PASSENGER AND VEHICULAR TRAFFIC

Weighted Average Travel Distance and Travel Time Via Present Ferries and Proposed Bridges Between San Francisco and the East Bay

Description	Reference item	Travel distance: Miles via present ferry routes: Between San Francisco zones and San Francisco ferry terminals	Travel distance: Miles via present ferry routes: Between San Francisco and East Bay ferry terminals	Travel distance: Miles via present ferry routes: Between East Bay zones and East Bay ferry terminals	Travel distance: Miles via present ferry routes: Total between San Francisco and East Bay zones	Travel distance: Miles via proposed bridge locations: No. 1 Rincon Hill to 7th and Cedar	Travel distance: Miles via proposed bridge locations: No. 2 Potrero Point to 7th and Cedar	Travel distance: Miles via proposed bridge locations: No. 3 Telegraph Hill to Goat Island and Key Pier	Travel distance: Miles via proposed bridge locations: No. 4 Rincon Hill to Goat Island and Key Pier	Travel distance: Miles via proposed bridge locations: No. 5 Hunters Point to Alameda	Travel time: Minutes via present ferry routes: Between San Francisco zones and San Francisco ferry terminals	Travel time: Minutes via present ferry routes: Between San Francisco and East Bay ferry terminals	Travel time: Minutes via present ferry routes: Between East Bay zones and East Bay ferry terminals	Travel time: Minutes via present ferry routes: Total between San Francisco and East Bay zones	Travel time: Minutes via proposed bridge locations: No. 1 Rincon Hill to 7th and Cedar	Travel time: Minutes via proposed bridge locations: No. 2 Potrero Point to 7th and Cedar	Travel time: Minutes via proposed bridge locations: No. 3 Telegraph Hill to Goat Island and Key Pier	Travel time: Minutes via proposed bridge locations: No. 4 Rincon Hill to Goat Island and Key Pier	Travel time: Minutes via proposed bridge locations: No. 5 Hunters Point to Alameda
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
INTERURBAN PASSENGER TRAFFIC	a																		
In operating period, 4:40 p.m. to 6:20 p.m.:	b																		
Between San Francisco zones and San Francisco stations on bridge approach	c					730	708	1 032	730	691					9 600	9 630	11 232	9 600	9 306
Between San Francisco stations and points on bridge approach in East Bay	d					6 070	8 507	7 894	7 327	11 019					14 430	20.628	20 346	16.560	27.384
Between East Bay zones and points on bridge approach in East Bay	e					5 277	4 915	4 426	4 426	6.100					23 820	23.130	21.774	21 774	26 142
Total between San Francisco zones and East Bay zones	f	1.007	3 120	6 857	11 044	12.077	14 190	13 352	12 483	17 810	11 502	[1]20 425	20 550	58 477	47.802	53 394	53.352	47.934	62.832
In one entire operating day:	g																		
Between San Francisco zones and San Francisco stations on bridge approach	h					.983	962	1 352	.983	930					10.524	10 512	12.582	10 524	10 092
Between San Francisco stations and points on bridge approach in East Bay	i					6 156	8 542	7 884	7.376	10 965					14 754	20 418	20.292	16 812	27 120
Between East Bay zones and points on bridge approach in East Bay	j					4 934	4 627	4 098	4 098	5 847					22 668	22.110	20 574	20.574	25.026
Total between San Francisco zones and East Bay zones	k	1.400	3.140	6 574	11.114	12.073	14 131	13 334	12 457	17.742	12.942	[1]19.696	25 556	58.204	47.940	53.040	53 448	47.910	62.238
VEHICULAR TRAFFIC	l																		
In one 24-hour day:	m																		
Between San Francisco zones and San Francisco terminal of bridge	n					2 176	3 550	2 309	2 170	4 698					10 308	10.550	11.298	10 368	21.144
Between San Francisco terminal and East Bay terminal of bridge	o					5 835	6 411	7 080	6 940	7 293					11.670	12 822	14 160	13 878	14 586
Between East Bay zones and East Bay terminal of bridge	p					5.097	4 995	4 430	4 430	6 425					21.714	21.504	18.960	18.960	23 058
Total between San Francisco zones and East Bay zones	q	2.473	3 780	6.593	12 840	13.108	14 962	13 819	13 546	18.415	11.825	[2]31.678	26 436	69.940	43.752	51.042	44 418	43.200	59 388
INTERURBAN AND VEHICULAR PASSENGERS COMBINED	r																		
Eastbound and westbound in one day:	s																		
Interurban passengers, 82.67%	t				9.188	9 981	11.682	11 023	10 298	14 567				48 117	39.637	43.848	44.185	39.607	51.452
Vehicular passengers 17.33%	u				2 220	2 272	2 593	2 395	2 348	3 191				12.121	7 582	8.846	7 698	7 488	10 292
Weighted average	v				11.414	12 253	14 275	13 418	[2]2 646	17 858				60.238	47.219	52 694	51.883	47.095	61.744

[1] Includes waiting time between boat arrivals and train departures at East Bay piers.
[2] Includes waiting time on pier and boat at ferry terminals.

TABLE No. 6. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

General Description of Traffic Speeds Used in Travel Time Studies

A. Interurban passenger service speeds:

1. In San Francisco—Zone centers to Ferry Building or Bridge Loop Stations:
   (a) Walking speed—3 miles per hour.
   (b) Street car speeds—Present weekday inbound daytime schedules.
2. Train speeds on bridge loops in San Francisco—12 miles per hour
3. Train speeds on bridge and connecting lines from loops—30 miles per hour.
4. Ferry service—Present time schedules.
5. In East Bay cities—Zone centers to ferries or bridge terminals:
   (a) To ferries—Present weekday eastward schedule.
   (b) To bridge terminals—Present time schedules, except within certain area near terminals where estimated speeds of 12 and 20 miles per hour adopted.

B. Vehicular traffic speeds:

1. In San Francisco—Zone centers to ferries or bridge terminals:
   (a) In congested area of downtown—10 and 12½ miles per hour.
   (b) On streets used in study—Outside of congested area—12½ and 15 miles per hour.
   (Examples: 12½ miles per hour on Van Ness Ave.: 15 miles per hour on Oak Street.)
2. On bridges between terminals—30 miles per hour.
3. Ferry Service:
   (a) Waiting time of vehicles on pier and boat before departure—
   Weighted average from observation ..... 8.44 minutes
   (b) Crossing time—
   Weighted average from observation ..... 22.37 minutes
   (Weighted average schedule time, 20.36 minutes.)
   (c) Unloading time—
   Weighted average from observation ..... .88 minutes
   (d) Total ..... 31.69 minutes
4. In East Bay cities—
   (a) In congested area of downtown—10 miles per hour.
   (b) On streets used in study—Outside of congested area—15 miles per hour.
   (c) Other places Berkeley Pier—25 miles per hour.
   Outside city limits—20 and 25 miles per hour.
   Between Main St. and Pacific Ave., Alameda, to Alameda Mole and to 7th and Peralta Sts., Oakland—30 miles per hour.

TABLE No. 7. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Comparative Travel Distances and Times of Interurban Passengers Between Representative Points in East Bay and San Francisco Interurban Passenger Center of Traffic Origin—4th and Market Sts.

	Representative points in East Bay								
	9th St. Line (S. P.), Ramona Avenue Station	Shattuck Line (S. P.), Berkeley Station	Berkeley Line (Key), Oakland Avenue Station	Piedmont Line (Key), Oakland Ave. Station	22d St. Line (Key), Broadway Station	18th St. Line (S. P.), 14th and Webster Station	12th St. Line (Key), 12th and Broadway Station	7th St. Line (S. P.), Havens Court Station	Encinal Avenue Line (S. P.), Park St. South Station
Distance in miles:									
Total, via present route	12.31	10.91	10.65	10.20	9.15	8.61	9.61	13.41	9.91
Total, via Bridge No. 1	13.21	11.81	11.98	11.53	9.18	9.51	8.57	14.19	10.36
Total, via Bridge No. 4	12.51	11.11	11.18	10.73	8.90	9.46	9.26	15 41	13 53
Travel time in minutes:									
Total, via present route	54.92	46.88	43.64	51.15	42.79	43.69	41.89	60.69	43.57
Total, via Bridge No. 1	37.33	33.33	33.96	37.88	27.63	30.93	26.46	46.03	29.18
Total, via Bridge No. 4	35.10	31.10	30.68	34.60	24.64	28.30	26.00	48.91	38.00
Difference between: (First mentioned larger than second)=saving in time.									
Present route and bridge No. 1	17.59	13.55	9.68	13.27	15 16	12.76	15.43	14.66	14.39
Present route and bridge No. 4	19.82	15.78	12.96	16.55	18.16	15.39	15.89	11.78	5 57
Bridge No. 1 and Bridge No. 4	2.23	2.23	3.28	3.28	2.99	2.63	0.46	—2.88	—8 82

TABLE No. 8. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Comparative Travel Distances and Times of Vehicles between Representative Points in East Bay and San Francisco Vehicular Center of Traffic Origin at City Hall (Grove and Polk)

	Representative points in East Bay					
	San Pablo Avenue at County Line	Shattuck and University (Berkeley)	Highland and Magnolia (Piedmont)	12th and Broadway (Oakland)	E. 14th St. and Washington (San Leandro)	Park St. and Encinal (Alameda)
Distance in miles, total via—						
Berkeley Ferry	13.06	12.20				
Oakland Ferry, 7th St.	14.43	12.47	12.68	9.07	17.58	
Alameda						11.55
Bridge No. 1	14.72	12.76	12.97	9.41	17.92	11 60
Bridge No. 4	14.21	12.39	12.59	10.42	19.56	14.93
Bridge No. 5	20.69	18.68	18.89	14.87	23.38	14.32
Travel time in minutes, total via—						
Berkeley Ferry	66.52	63.08				
Oakland Ferry, 7th St.	75.23	67.39	68.23	57.16	91.96	
Alameda Ferry						69.69
Bridge No. 1	48.77	40.93	41.77	30.89	65.69	40 75
Bridge No. 4	44.64	37.36	38.16	32 79	69.67	54.29
Bridge No. 5	66.87	58.83	59.67	45.80	80.59	51.70
Differences between (first mentioned larger than second)= Saving in time:						
Berkeley Ferry and Bridge No. 1	17.75	22.15				
Berkeley Ferry and Bridge No 4	21.88	25.72				
Berkeley Ferry and Bridge No 5	−0.35	4.25				
Oakland Ferry and Bridge No 1	26.46	26.46	26.46	26.27	26.27	
Oakland Ferry and Bridge No. 4	30.59	30.03	30.07	24.37	22.29	
Oakland Ferry and Bridge No. 5	8.36	8.56	8.56	11.36	11.37	
Alameda Ferry and Bridge No. 1						28.94
Alameda Ferry and Bridge No. 4						15.40
Alameda Ferry and Bridge No. 5						17.99
Bridges Nos. 1 and 4	4.13	3.57	3.61	−1.90	−3.98	−13.54
Bridges Nos. 1 and 5	−18.10	−17.90	−17.99	−14.91	−14.90	−10.95
Bridges Nos. 4 and 5	−22.23	−21.47	−21.51	−13.01	−10.92	2.59

TABLE No. 9. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Direction of Growth in East Bay Cities

I. Indications from Interurban Passenger Traffic

Geographical Direction	Per cent of total		
	1925 Survey	1929 Survey	Trend
North Zones 56 to 70, inclusive, 74, 75, 85, 96 and 98	51.60	49.55	—2 05
Neutral Zones 51 and 52 (Central Oakland)	12.45	12.38	—0 07
South Zones 50, 53, 54, 55, 71, 72, 73 and 76 to 84, inclusive, and 97	35.95	38.07	+2 12

Data from Eastbound Interurban Passenger Traffic Censuses of December 3, 1925 and December 12, 1929

II. Indications from Locations of New Industries

	New industries located yearly			
	North of 18th Street		South of 18th Street	
	Number	Per cent of years, total	Number	Per cent of years, total
1924	36	33.0	73	67.0
1925	49	40.5	72	59.5
1926	46	44.7	57	55.3
1927	51	43.2	67	56.8
1928	43	34.4	82	65.6
1929	48	43.6	62	56.4
Totals	273	39.8	413	60 2

Basic data supplied by Oakland Chamber of Commerce.

III. Indications from Telephone Station Development

Direction	Central office districts	Per cent of year's total			Trend
		1930	1938	1945	'30 to '45
North	Berkeley, Piedmont and Richmond	42.8	40.6	39.8	—3.0
Neutral	Main	27.8	27.2	29.0	+1.2
South	Alameda, Fruitva e and Trinidad	29.4	32.2	31.2	+1 8

Basic data supplied by The Pacific Telephone and Telegraph Co.

Table No. 10

SAN FRANCISCO BAY TRAFFIC STUDY

Transbay Train-Ferry Passengers Between San Francisco and East Bay. 1915-1929.

YEAR	TOTAL PASSENGERS								
	K.S.T.Co. Key Div'n. (1)	S.P.Co. Oak. Pier (2)	Total Col. (1) and (2) (3)	S.P. Co. Alam. Pier (4)	S.P. Co. Loc. Ferry (5)	Total Col. (3+4-5) (6)	S.P. Co. Main Line (7)	S.F. & W.P. Main Line (8)	Total Col. (6-7-8) (9)
1915	16,671,427	13,504,352	30,175,779	5,823,474	134,670	36,133,923	2,102,822	514,061	38,750,806
1916	13,233,410	12,645,354	25,878,764	5,453,323	105,329	31,437,416	1,509,456	300,981	33,247,853
1917	13,733,592	13,601,936	27,335,528	5,835,390	130,041	33,300,959	1,854,411	345,548	35,500,918
1918	14,613,670	14,519,981	29,133,651	5,721,983	156,725	35,012,359	2,025,932	170,465ø	37,208,756
1919	14,805,593	16,777,058	31,582,651	6,065,035	175,360	37,823,046	1,868,300	ø	39,691,346
1920	15,062,667	16,407,205	31,469,872	6,058,032	90,906	37,618,810	1,938,877	94,743ø	39,652,430
1921	15,033,611	15,929,986	30,963,597	5,815,197	68,624	36,847,418	1,588,901	218,503	38,654,822
1922	15,551,624	15,546,558	31,098,182	5,720,577	60,528	36,879,287	1,515,340	266,031	38,660,658
1923	16,685,643	16,404,673	33,090,316	5,723,641	124,028	38,937,985	1,546,661	275,532	40,760,178
1923	17,579,206	16,858,435	34,437,641	4,951,501	146,759	39,535,901	1,475,261	273,431	41,284,593
1925	17,244,851	17,441,806	34,686,657	4,984,129	176,311	39,847,097	1,376,781	257,805	41,481,683
1926	15,720,837	16,579,762	32,300,599	4,826,324	145,130	37,272,053	1,432,035	244,483	38,948,571
1927	16,045,331	15,616,530	31,661,861	4,834,355	144,519	36,640,735	1,426,194	207,724	38,274,653
1928	15,333,998	15,338,032	30,672,030	4,620,371	150,463	35,442,864	1,371,487	169,234	36,983,585
1929	14,919,253	14,480,779	29,400,032	4,799,915	159,685	34,359,632	1,424,670	139,553	35,923,855

ø Passengers carried over S.P. Company Ferry from August 17,1918 to January 11,1921.

TABLE No. 11. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Transbay Vehicular Ferry Service between San Francisco and East Bay, 1915-1929

Year	Number of vehicle trips							
	First and Broadway (1)	Oakland Pier (2)	Total columns 1 and 2 (3)	Alameda (4)	Total columns 3 and 4 (5)	Richmond (6)	Berkeley (7)	Total columns 5, 6 and 7 (8)
1915	364,558	----------	364,558	----------	364,558	----------	----------	364,558
1916	418,189	----------	418,189	----------	418,189	----------	----------	418,189
1917	521,936	----------	521,936	----------	521,936	----------	----------	521,936
1918	545,344	----------	545,344	----------	545,344	----------	----------	545 344
1919	679,681	----------	679,681	----------	679,681	----------	----------	679,681
1920	773,294	----------	773,294	----------	773,294	----------	----------	773,294
1921	730,085	[1]98,697	828,782	----------	828,782	----------	----------	828,782
1922	677,898	256,647	934,545	----------	934,545	----------	----------	934,545
1923	439,874	785,062	1,224,936	----------	1,224,936	----------	----------	1,224,936
1924	237,358	1,105,610	1,342,968	----------	1,342,968	----------	----------	1,342,968
1925	148,206	1,391,123	1,539,329	----------	1,539,329	[2]19,207	----------	1,558,536
1926	81,893	2,547,431	2,629,324	[3]49,545	2,678,869	28,197	----------	2,707,05 5
1927	27,932	2,776,453	2,804,385	171,668	2,976,053	54,512	[4]506,216	3,536,781
1928	18,671	2,802,672	2,821,343	210,640	3,031,983	95,956	1,022,527	4,150,466
1929	18,077	3,058,101	3,076,178	196,960	3,273,138	91,401	1,125,974	4,490,513

[1] Service started July, 1921.
[2] Service started January, 1925.
[3] Service started September, 1926.
[4] Service started June, 1927.

TABLE No. 12. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Transbay Vehicular Ferry Service between San Francisco and East Bay, 1915-1929

Year	Number of passengers c .rried on vehicul .r ferries							
	First and Broadway (1)	Oakland Pier (2)	Total columns 1 and 2 (3)	Alameda (4)	Total columns 3 and 4 (5)	Richmond (6)	Berkeley (7)	Total columns 5, 6 and 7 (8)
1915	1,749,567	----------	1,749,567	----------	1,749,567	----------	----------	1,749,567
1916	1,633,561	----------	1,633,561	----------	1,633,561	----------	----------	1,633,561
1917	1,905,470	----------	1,905,470	----------	1,905,470	----------	----------	1,905,470
1918	1,962,499	----------	1,962,499	----------	1,962,499	----------	----------	1,962,499
1919	2,300,520	----------	2,300,520	----------	2,300,520	----------	----------	2,300,520
1920	2,609,982	----------	2,609,982	----------	2,609,982	----------	----------	2,609,982
1921	2,539,875	[1]278,172	2,818,047	----------	2,818,047	----------	----------	2,818,047
1922	2,030,404	716,578	2,746,982	----------	2,746,982	----------	----------	2,746,982
1923	1,497,923	1,772,201	3,270,124	----------	3,270,124	----------	----------	3,270,124
1924	1,039,941	2,423,828	3,463,769	----------	3,463,769	----------	----------	3,463,769
1925	830,967	3,017,213	3,848,180	----------	3,848,180	[2]237,329	----------	4,085,509
1926	844,646	5,469,481	6,314,127	[3]125,597	6,439,724	266,946	----------	6,706,670
1927	604,295	5,753,618	6,357,913	367,049	6,724,962	378,670	[4]1,171,132	8,274,864
1928	543,118	5.797,048	6,340,166	439,967	6,780,133	578,045	2,252,939	9,611,117
1929	531,846	6,283,551	6,815,397	352,767	7,168,164	605,913	2,399,951	10,174,028

[1] Service started July, 1921.
[2] Service started January, 1925.
[3] Service started September, 1926.
[4] Service started June, 1927.

TABLE No. 13. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY. FORECAST OF FUTURE TRANSBAY PASSENGER TRAFFIC

Rail and Vehicular Ferry Service Only

Year	Number of passengers					Estimated population	Passengers per capita			Total vehicular and rail passengers, with bridge completed 1-1-'37					
													Passengers per capita		
	Interurban	Main line	Total interurban and main line	Vehicular	Total rail and vehicular		Total rail	Vehicular	Total	Rail	Vehicular	Total	Total rail	Total vehicular	Total rail and vehicular
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1915	36,133,923	2,616,883	38,750,806	1,749,567	40,500,373	760,000	50.99	2.30	53.29						
1916	31,437,416	1,810,437	33,247,853	1,633,561	34,881,414	779,200	42.67	2.10	44.77						
1917	33,300,959	2,199,959	35,500,918	1,905,470	37,406,388	797,900	44.49	2.39	46.88						
1918	35,012,359	2,196,397	37,208 756	1,962 499	39,171,255	816,100	45.59	2.40	47.99						
1919	37,823,046	1,868,300	39,691,346	2,300,520	41,991,866	833,800	47.60	2.76	50.36						
1920	37,618,810	2,033,620	39,652,430	2,609.982	42,262,412	850.850	46.60	3.07	49.67						
1921	36,847,418	1,807,404	38.654,822	2,818,047	41,472,869	875,000	44.18	3.22	47.40						
1922	36,879,287	1,781,371	38,660,658	2,746,982	41,407,640	904,000	42.76	3.04	45.80						
1923	38,937,985	1,822,193	40,760,178	3,270,124	44,030,302	938,000	43.45	3.49	46.94						
1924	39,535,901	1,748,692	41,284,592	3,463,769	44,748,362	976,000	42.30	3 55	45.85						
1925	39,847,097	1,634,586	41,481,683	4,085,509	45,567,192	1,017,000	40.79	4.02	44.81						
1926	37,282,053	1,676,518	38,948,571	6,706,670	45,655,241	1,061,000	36.72	6.32	43.04						
1927	36,640,735	1,633,918	38,274,653	8,274,864	46,549.517	1,107,000	34.58	7.48	42 06						
1928	35,442,864	1,540,721	36,983,585	9,611,117	46,594,702	1,155,000	32.02	8.32	40.34						
1929	34,359,632	1,564,223	35,923,855	10,174,028	46,097,883	1,205,000	29.81	8.44	38.25						
1930			36,024,000	10,976,000	47,000,000	1,257,000	28.66	8.73	37.39						
1931			36,234,000	11,766,000	48,000,000	1,311,000	27.64	8.97	36.61						
1932			36,394,000	12,606,000	49,000,000	1,366,000	26.64	9.23	35.87						
1933			36,615,000	13,385,000	50,000,000	1,422,000	25.75	9.41	35.16						
1934			36,874,000	14,126,000	51,000,000	1,479,000	24.93	9.55	34.48						
1935			37,106,000	14,894,000	52,000,000	1,535,000	24.17	9.71	33.88						
1936			37,376,000	15,624,000	53,000,000	1,590,000	23.51	9.83	33.34						
1937			37,662,000	16,338,000	54,000,000	1,644,000	22.91	9.94	32.85	36,028,000	19,606,000	55,634,000	21.91	11 93	33.84
1938			37,944,000	17,056,000	55,000,000	1,697,000	22.36	10 05	32.41	36,238,000	20,467,000	56,705,000	21.35	12.06	33.41
1939			38,284,000	17,716,000	56,000,000	1,749,000	21.89	10.13	32.02	36,512,500	21,259,000	57,771,500	20.87	12.16	33.03
1940			38,599,000	18,401,000	57,000,000	1,800,000	21.44	10.23	31.67	36,759,000	22,081,000	58,840,000	20.42	12.27	32 69

Table No. 14

SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Forecast of Future Transbay
Vehicular Traffic

Ferry Service Only

YEAR	San Francisco & Alameda Counties			Transbay Vehicular Traffic			Vehicular Passengers		Total Vehicular Traffic with Bridge Completed			
	Population	Auto Reg'n	Cars per 1000	Total	Per Capita	Per Car	Total	Per Car	Total Vehicular Traffic	Per Capita	Per Car	Total Vehicular Passengers
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1915	760,000	29,203	38.4	364,558	.48	12.5	1,749,567	4.80				
1916	779,200	40,780	52.3	418,189	.54	10.3	1,633,561	3.91				
1917	797,900	52,074	65.3	521,936	.65	10.0	1,905,470	3.65				
1918	816,100	60,454	74.1	545,344	.67	9.0	1,962,499	3.60				
1919	833,800	81,428	97.7	679,681	.82	8.3	2,300,520	3.39				
1920	850,850	94,742	111.3	773,294	.91	8.2	2,609,982	3.38				
1921	875,000	108,708	124.2	828,782	.95	7.6	2,818,047	3.40				
1922	904,000	134,156	148.4	934,545	1.03	7.0	2,746,982	2.94				
1923	938,000	164,396	175.3	1,224,936	1.31	7.5	3,270,124	2.67				
1924	976,000	195,541	200.3	1,342,968	1.38	6.9	3,463,769	2.58				
1925	1,017,000	219,374	215.7	1,558,536	1.53	7.1	4,085,509	2.62				
1926	1,061,000	246,147	232.0	2,707,066	2.55	11.0	6,706,670	2.48				
1927	1,107,000	259,961	234.8	3,536,781	3.19	13.6	8,274,864	2.34				
1928	1,155,000	277,746	240.5	4,150,466	3.59	14.9	9,611,117	2.32				
1929	1,205,000	297,875	247.2	4,490,513	3.73	15.1	10,174,028	2.27				
1930	1,257,000	321,800	256.0	4,900,000	3.90	15.2	10,976,000	2.24				
1931	1,311,000	346,100	264.0	5,300,000	4.04	15.3	11,766,000	2.22				
1932	1,366,000	371,500	272.0	5,730,000	4.20	15.4	12,606,000	2.20				
1933	1,422,000	396,000	278.0	6,140,000	4.32	15.5	13,385,000	2.18				
1934	1,479,000	422,000	285.0	6,540,000	4.42	15.5	14,126,000	2.16				
1935	1,535,000	448,000	292.0	6,960,000	4.53	15.5	14,894,000	2.14				
1936	1,590,000	472,000	297.0	7,370,000	4.64	15.6	15,624,000	2.12				
1937	1,644,000	498,000	303.0	7,780,000	4.73	15.6	16,338,000	2.10	9,336,000	5.70	18.7	19,606,000
1938	1,697,000	525,000	309.0	8,200,000	4.83	15.6	17,056,000	2.08	9,840,000	5.80	18.7	20,457,000
1939	1,749,000	550,000	314.0	8,600,000	4.92	15.6	17,716,000	2.06	10,320,000	5.90	18.7	21,259,000
1940	1,800,000	576,000	320.0	9,020,000	5.01	15.7	18,401,000	2.04	10,824,000	6.01	18.8	22,081,000

TABLE No. 15

Place	1880	1890	1900	1910	1920	1930[1]
Alameda County	62,976	93,864	130,197	246,131	344,177	[2]500,000
San Francisco County	233,959	298,997	342,782	416,912	506,676	625,974
San Francisco, City	233,959	298,997	342,782	416,912	506,676	625,974
Alameda, City			16,464	23,383	28,806	34,847
Berkeley, City			13,214	40,434	56,036	81,543
Oakland, City			66,960	150,174	216,261	284,213
Alameda and San Francisco counties	296,935	392,861	472,979	663,043	850,853	1,125,974

[1] Figures for 1930 unofficial.
[2] Estimated.

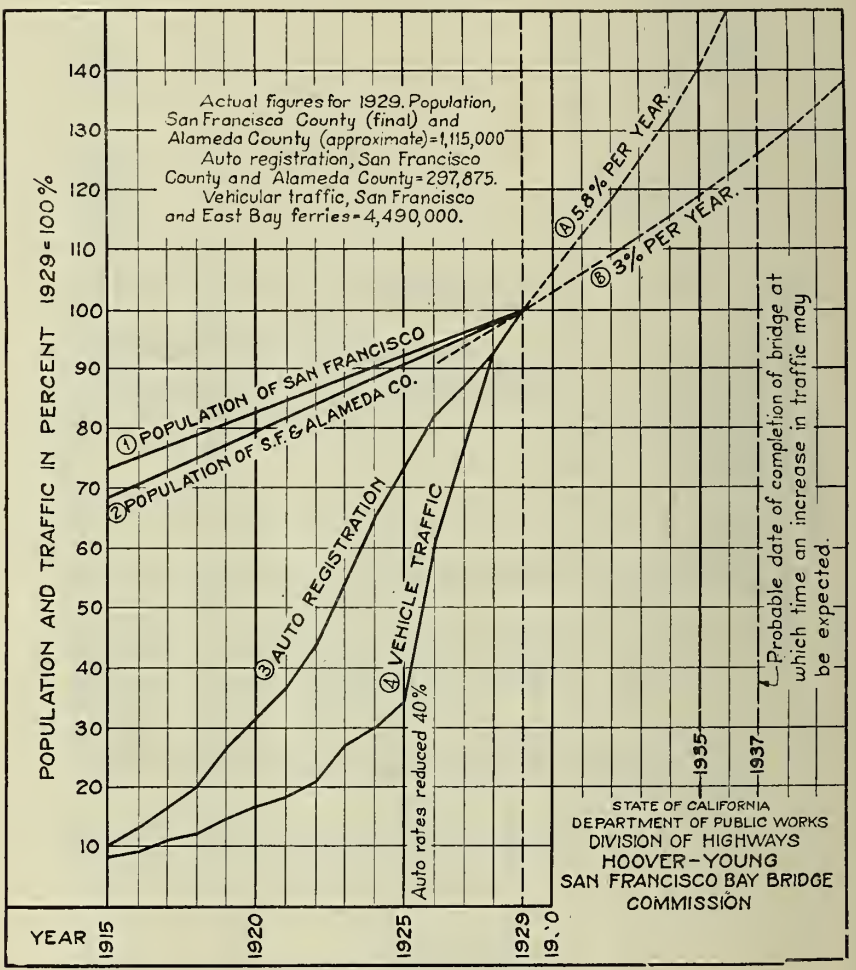


PLATE No. 1

Curves showing rates of increase in population, auto registration and vehicular ferry traffic 1915–1929. Also projected possible rate of increase in traffic 1929–1940. Percentage based on figures for 1929 = 100%.

TABLE No. 16. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Statement of Difference in Vehicular Travel Distance and Time Between San Francisco and East Bay Zones via Present Ferry and the Several Bridge Locations and Computation of Additional Running Expense per Motor Vehicle per Trip of Operating Over Bridge Instead of Standing on Ferry Boat. (This Expense Does Not Include Any Consideration of Fares or Time Lost or Gained En Route.)

Location number	Weighted average distance in miles				Additional miles of operation per vehicle per trip, via bridge	Time in minutes, bridge route less than ferry
	Between San Francisco and East Bay zones via bridge route			Between terminals of present ferries		
	Miles	Via ferry route	Bridge exceeds ferries			
1	13.108	12.846	.262	3.780	4.042	26.188
2	14.962	12.846	2.116	3.780	5.896	18.898
3	13.819	12.846	.973	3.780	4.753	25.522
4	13.546	12.846	.700	3.780	4.480	26.734
5	18.416	12.846	5.570	3.780	9.350	10.552

Additional Running Expense per Motor Vehicle per Trip of Operating Over Bridge vs. Standing on Ferry Boat

Classification	Motor vehicles					
	Per cent of total	Number of units, year 1940	Additional miles of operation	Total vehicle miles	Running cost per vehicle per mile	Total added running expense
Via Bridge Location No. 1:						
Automobiles	87	9,417,000	4.042	38,063,514	$0 04	$1,522,541
Trucks	12	1,299,000	4.042	5,250,558	12	630,067
Motor coaches	1	108,000	4.042	436,536	10	43,654
Totals per year	100	10,824,000		43,750,608		$2,196,262
Weighted average			4.042		$0 0502	
Per average vehicle per trip						20.3 cents
Via Bridge Location No. 4:						
Automobiles	87	9,417,000	4.480	42,188,160	$0 04	$1,687,526
Trucks	12	1,299,000	4.480	5,819,520	12	698,342
Motor coaches	1	108,000	4.480	483,840	10	48,384
Totals per year	100	10,824,000		48,491,520		$2,434,252
Weighted average			4.480		$0 0502	
Per average vehicle per trip						22.5 cents
Via Bridge Location No. 5:						
Automobiles	87	9,417,000	9.350	88,048,950	$0 04	$3,521,958
Trucks	12	1,299,000	9.350	12,145,650	12	1,457,478
Motor coaches	1	108,000	9.350	1,009,800	10	100,980
Totals per year	100	10,824,000		101,204,400		$5,080,416
Weighted average			9.350		$0 0502	
Per average vehicle per trip						46.9 cents

Table No. 17

SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Estimated Interurban Passenger Service Operating Cost Via Several Bridge Locations
1929 Traffic

Item	Present Ferry Operations	Bridge Location 1	Bridge Location 2	Bridge Location 3	Bridge Location 4	Bridge Location 5
(1) Estimated Revenue Car Miles	-	8,141,000	9,290,000	8,451,000	8,491,000	10,178,000
(2) Number of Passengers:						
Interurban & S.P. Co. Main Line	35,784,302	35,784,302	35,784,302	35,784,302	35,784,302	35,784,302
(3) Equivalent Single Track Miles on Bridge and Terminals	-	22.00	32.13	26.75	26.68	36.16
(4) Cost of New Equipment	-	$ 4,384,000	$ 5,632,000	$ 4,736,000	$ 4,768,000	$ 7,712,000
(5) Operating Revenue	$ 6,059,231	6,059,231	6,059,231	6,059,231	6,059,231	6,059,231
(6) Operating Expense:						
(a) Maintenance of Ways and Structures	993,648	614,700	583,000	556,700	556,700	600,000
(b) Maintenance of Equipment	1,086,348	814,100	929,000	845,100	849,100	1,017,800
(c) Power	417,921	460,000	524,900	477,500	479,700	575,000
(d) Transportation	2,853,268	1,628,200	1,854,000	1,690,200	1,698,200	2,035,600
(e) Traffic	2,070	4,000	4,600	4,200	4,300	5,100
(f) General	412,064	407,000	469,500	422,500	424,500	508,900
TOTAL OPERATING EXPENSE:	$ 5,765,319	3,928,000	4,365,000	3,996,200	4,012,500	4,742,400
(7) Net	293,912	2,131,231	1,694,231	2,063,031	2,046,731	1,316,831
(8) Net Revenue-Auxiliary Operation	234,209	-	-	-	-	-
(9) Saving Possible Through Elimination of Duplication	289,000	-	-	-	-	-
(10) Taxes	441,329	441,329	441,329	441,329	441,329	441,329
(11) Net Available	375,792	1,689,902	1,252,902	1,621,702	1,605,402	875,502
(a) Interest on Cost of New Equipment at 7%	-	306,880	394,240	331,520	333,760	539,840
(b) Maintenance of Ways & Structures on Bridge, Terminals, Approaches at $5,000 per Mile	-	110,000	160,000	133,750	133,400	180,800
(12) Net Available for:		$1,273,022	$ 798,662	$1,156,432	$1,138,242	$ 154,862
(a) Return on Utility Capital Still Operative						
(b) Interest on Cost of Ways and Structures on Bridge, Approaches and Terminals						
(c) Maintenance of Bridge, Terminals and Approaches						
(d) Interest and Amortization on Cost of Bridges, Terminals and Approaches.						

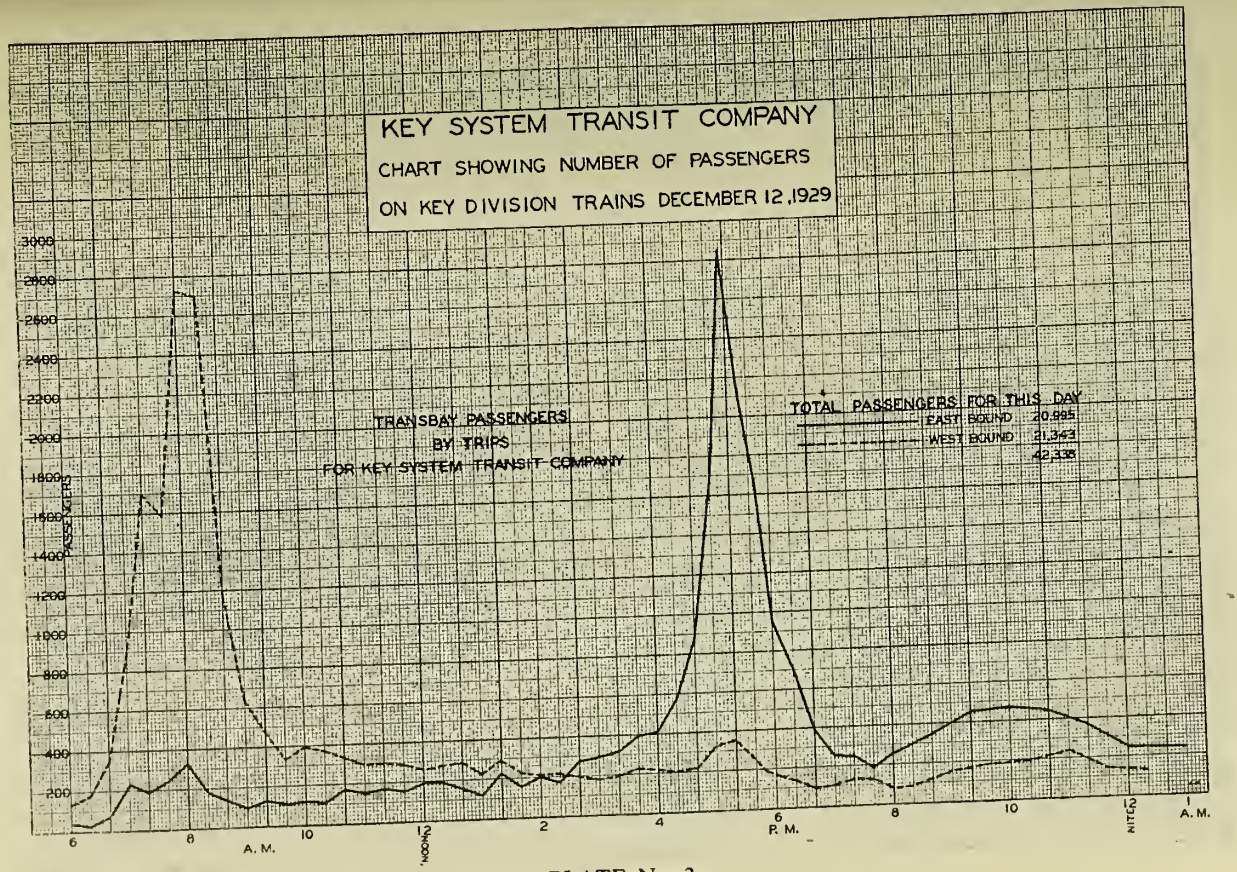

KEY SYSTEM TRANSIT COMPANY
CHART SHOWING NUMBER OF PASSENGERS
ON KEY DIVISION TRAINS DECEMBER 12, 1929
TRANSBAY PASSENGERS
BY TRIPS
FOR KEY SYSTEM TRANSIT COMPANY
TOTAL PASSENGERS FOR THIS DAY
EAST BOUND 20,995
WEST BOUND 21,343
42,338
PASSENGERS
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
6
8
10
12 NOON
2
4
6
8
10
1
A. M.
P. M.
MIDNIGHT

PLATE No. 2

HOURLY EAST & WEST BOUND
INTERURBAN PASSENGER SERVICE
BETWEEN
SAN FRANCISCO & EAST BAY CITIES
DECEMBER 12, 1929.
KEY SYSTEM TRANSIT & SOUTHERN PACIFIC COMPANIES COMBINED
INTERURBAN PASSENGERS
EASTBOUND
WESTBOUND
NOON
A.M.
P.M.
NITE

PLATE No. 3

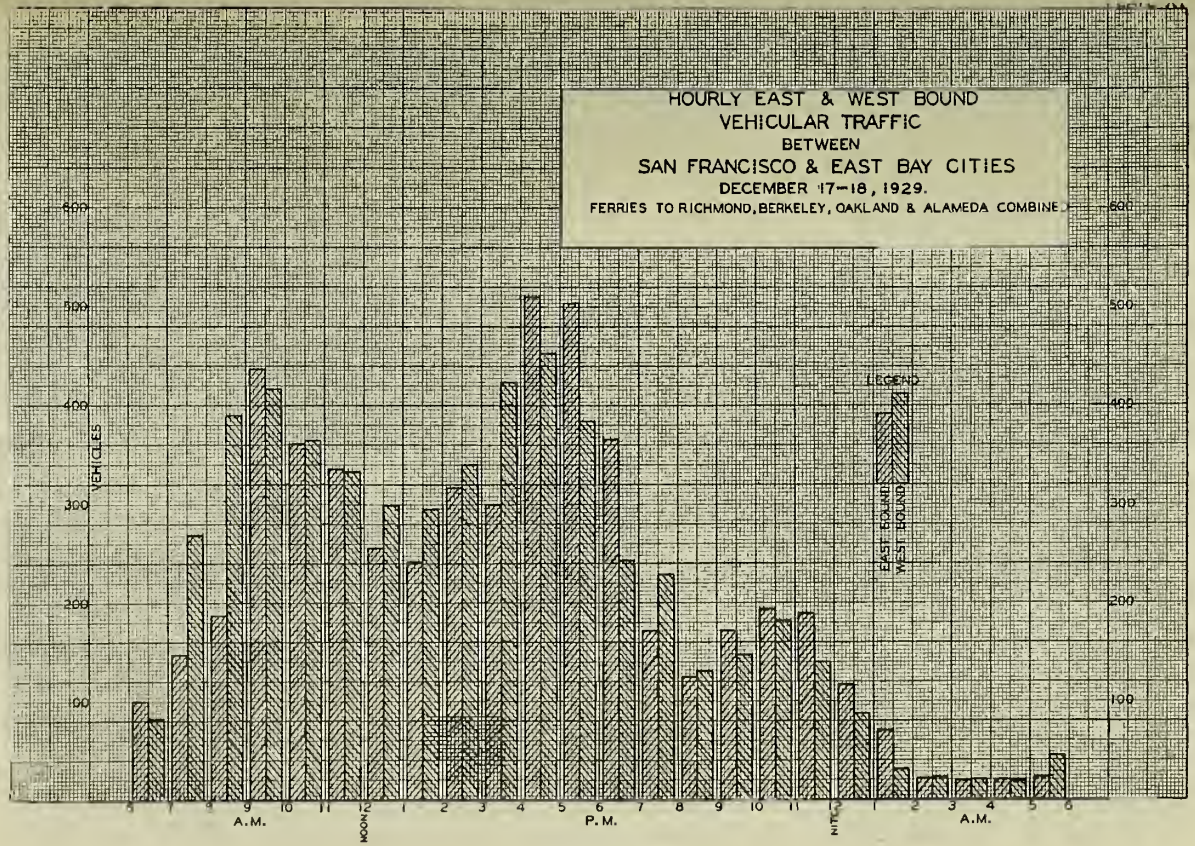

HOURLY EAST & WEST BOUND
VEHICULAR TRAFFIC
BETWEEN
SAN FRANCISCO & EAST BAY CITIES
DECEMBER 17-18, 1929.
FERRIES TO RICHMOND, BERKELEY, OAKLAND & ALAMEDA COMBINED
VEHICLES
600
500
400
300
200
100
LEGEND
EAST BOUND
WEST BOUND
A.M.
NOON
P.M.
MIDN.
A.M.

PLATE No. 4

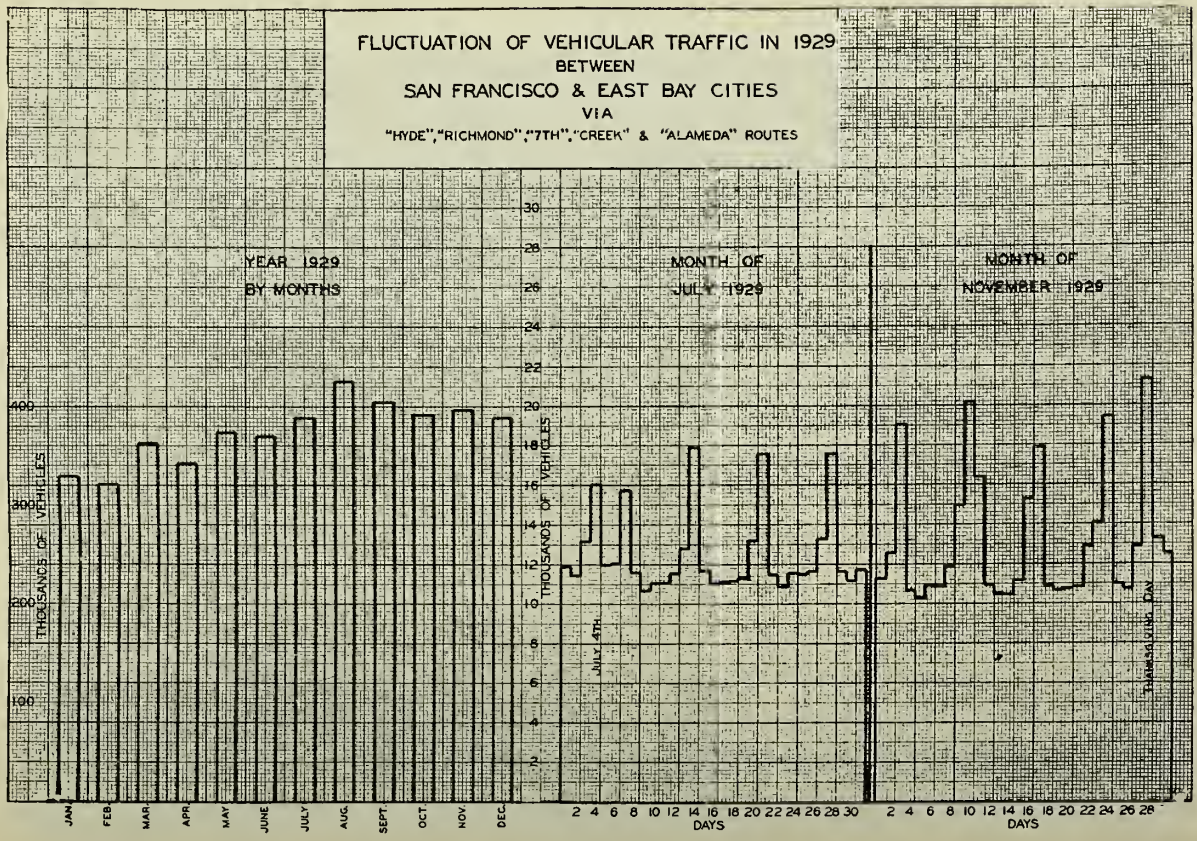

FLUCTUATION OF VEHICULAR TRAFFIC IN 1929
BETWEEN
SAN FRANCISCO & EAST BAY CITIES
VIA
"HYDE","RICHMOND","7TH","CREEK" & "ALAMEDA" ROUTES
YEAR 1929
BY MONTHS
MONTH OF
JULY 1929
MONTH OF
NOVEMBER 1929
THOUSANDS OF VEHICLES
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT
NOV.
DEC.
JULY 4TH.
THANKSGIVING DAY
DAYS
DAYS

PLATE No. 5

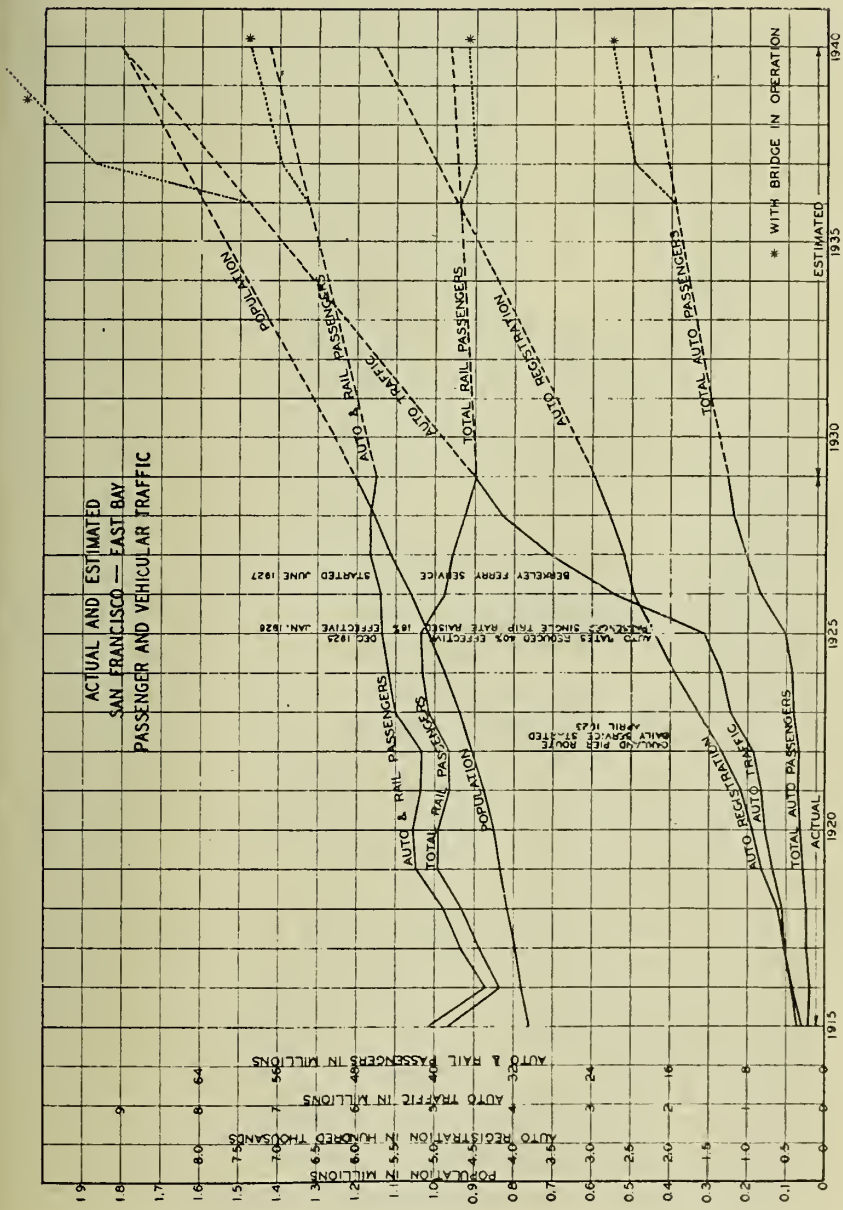

ACTUAL AND ESTIMATED
SAN FRANCISCO — EAST BAY
PASSENGER AND VEHICULAR TRAFFIC
POPULATION
AUTO & RAIL PASSENGERS
AUTO TRAFFIC
TOTAL RAIL PASSENGERS
AUTO REGISTRATION
TOTAL AUTO PASSENGERS
BERKELEY FERRY SERVICE STARTED JUNE 1927
AUTO RATES REDUCED 40% EFFECTIVE DEC. 1925
"KEY ROUTE" SINGLE FARE RATE RAISED 16% EFFECTIVE JAN. 1928
CONSOLIDATED PIER ROUTE FERRY SERVICE DISCONTINUED APRIL 1, 1923
AUTO REGISTRATION
AUTO TRAFFIC
TOTAL AUTO PASSENGERS
ACTUAL
ESTIMATED
* WITH BRIDGE IN OPERATION
POPULATION IN MILLIONS
AUTO REGISTRATION IN HUNDRED THOUSANDS
AUTO TRAFFIC IN MILLIONS
AUTO & RAIL PASSENGERS IN MILLIONS
1915
1920
1925
1930
1935
1940

PLATE No. 6

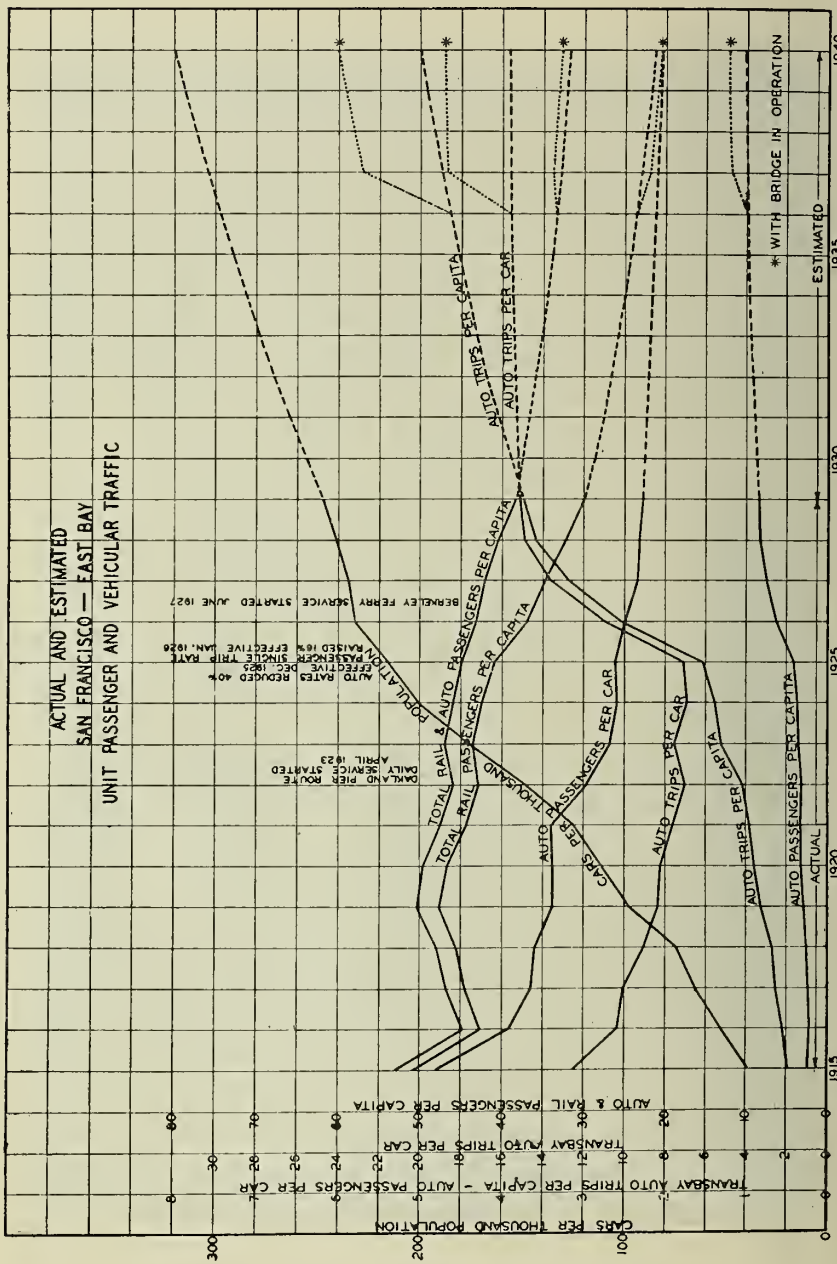

ACTUAL AND ESTIMATED
SAN FRANCISCO — EAST BAY
UNIT PASSENGER AND VEHICULAR TRAFFIC
BERKELEY FERRY SERVICE STARTED JUNE 1927
POSTAL AUTO RATES REDUCED 40%
EFFECTIVE DEC. 1925
PASSENGER SINGLE TRIP RATE
RAISED 16% EFFECTIVE JAN. 1926
OAKLAND PIER ROUTE
OAILY SERVICE STARTED
APRIL 1923
TOTAL RAIL & AUTO PASSENGERS PER CAPITA
TOTAL RAIL PASSENGERS PER CAPITA
AUTO PASSENGERS PER CAR
AUTO TRIPS PER CAR
AUTO TRIPS PER CAPITA
AUTO PASSENGERS PER CAPITA
ACTUAL
ESTIMATED
* WITH BRIDGE IN OPERATION
CARS PER THOUSAND POPULATION
TRANSBAY AUTO TRIPS PER CAPITA - AUTO PASSENGERS PER CAR
TRANSBAY AUTO TRIPS PER CAR
AUTO & RAIL PASSENGERS PER CAPITA
1915
1920
1925
1930
1935
1940

PLATE No. 7

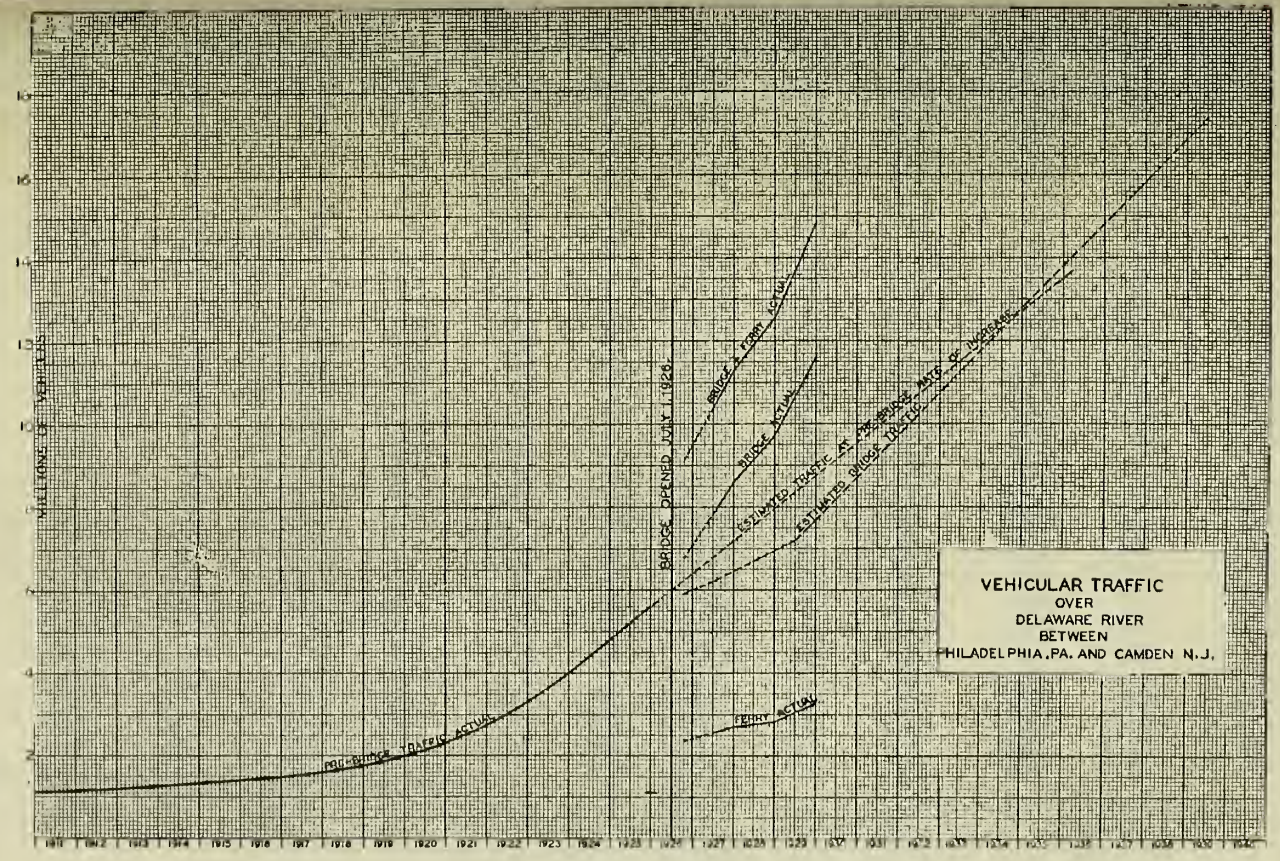

MILLIONS OF VEHICLES
BRIDGE OPENED JULY 1, 1926
BRIDGE & FERRY ACTUAL
BRIDGE ACTUAL
ESTIMATED TRAFFIC AT 4% BRIDGE RATE OF INCREASE
ESTIMATED BRIDGE TRAFFIC
FERRY ACTUAL
PRE-BRIDGE TRAFFIC ACTUAL
VEHICULAR TRAFFIC
OVER
DELAWARE RIVER
BETWEEN
PHILADELPHIA, PA. AND CAMDEN N.J.

PLATE No. 8

Table 18

SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Grand Summary of Eastbound Passengers Handled by Southern Pacific Company and Key System Transit Company on One Operating Day - Traffic Census of December 12,1929

Zone	5:00 A.M. to 4:39 P.M.: S.P.	Key	Total	4:40 P.M. to 6:20 P.M.: S.P.	Key	Total	6:21 P.M. to 2:00A.M.: S.P.	Key	Total	Total Operating Day: S.P.	Key	Total
NUMBER OF PASSENGERS BY ZONES OF ORIGIN:												
1	1207	996	2203	5311	3921	9232	1147	837	1984	7665	5754	13,419
2	380	240	620	1790	1138	2928	311	170	481	2481	1548	4,029
3	1863	1855	3718	2950	3013	5963	1357	1368	2725	6170	6236	12,406
4	215	113	328	809	664	1473	170	119	289	1194	896	2,090
5	742	511	1253	608	486	1094	405	400	805	1755	1397	3,152
6	421	127	548	547	417	964	160	104	264	1128	648	1,776
7	80	41	121	184	92	276	23	18	41	287	151	438
8	271	284	555	113	99	212	79	71	150	463	454	917
9	122	136	258	24	34	58	21	48	69	167	218	385
10	455	340	795	120	153	273	112	178	290	687	671	1,358
11	443	397	840	117	116	233	113	111	224	673	624	1,297
12	577	333	910	330	309	639	189	196	385	1096	838	1,934
13	87	30	117	196	106	302	35	15	50	318	151	469
14	32	24	56	59	39	98	10	2	12	101	65	166
15	64	33	97	20	15	35	4	16	20	88	64	152
16	152	61	213	12	16	28	19	16	35	183	93	276
17	89	51	140	7	6	13	10	14	24	106	71	177
18	137	100	237	28	48	76	26	30	56	191	178	369
19	205	155	360	39	41	80	52	46	98	296	242	538
20	23	12	35	21	11	32	4	9	13	48	32	80
21	201	191	392	36	20	56	26	49	75	263	260	523
22	5	0	5	3	0	3	0	0	0	8	0	8
23	42	31	73	5	14	19	9	14	23	56	59	115
24	24	24	48	5	1	6	10	9	19	39	34	73
25	49	54	103	9	12	21	4	4	8	62	70	132
26	43	43	86	7	5	12	4	8	12	54	56	110
27	0	0	0	0	0	0	0	0	0	0	0	0
28	196	56	252	97	47	144	56	32	88	349	135	484
46	0	3	3	7	5	12	4	0	4	11	8	19
47	29	5	34	8	1	9	5	0	5	42	6	48
48	11	13	24	11	1	12	4	1	5	26	15	41
Sub-T.	8165	6259	14424	13473	10830	24303	4369	3885	8254	26007	20974	46,981
0	736	19	755	163	0	163	215	2	217	1114	21	1,135
TOTAL:	8901	6278	15179	13636	10830	24466	4584	3887	8471	27121	20995	48,116

NOTE: Zone 0 - Passengers originated at Ferry Piers in East Bay.

NOTE: Zone 0 - Passengers originated at ferry piers in East Bay.

(Continued)

ZONE	5:00 A.M. to 4:39 P.M. S.P.	Key	Total	4:40 P.M. to 6:20 P.M. S.P.	Key	Total	6:21 P.M. to 2:00 A.M. S.P.	Key	Total	Total Operating Day S.P.	Key	Total
NUMBER OF PASSENGERS BY ZONES OF DESTINATION:												
50	30	0	30	10	0	10	2	0	2	42	0	42
51	273	117	390	202	131	333	109	95	204	584	343	927
52	1,239	1,861	1,100	416	723	1,139	256	507	763	1,911	3,091	5,002
53	1,300	27	1,327	270	8	278	254	7	261	1,824	42	1,866
54	618	0	618	1,279	0	1,279	469	1	470	2,366	1	2,367
55	344	261	605	361	772	1,133	141	310	451	846	1,343	2,189
56	23	218	241	34	599	633	18	149	167	75	966	1,041
57	25	489	514	60	1,230	1,290	11	454	465	96	2,173	2,269
58	17	134	151	7	226	233	14	74	88	38	434	472
59	481	146	627	14	65	79	28	62	90	523	273	796
60	117	548	665	231	1,958	2,189	103	522	625	451	3,028	3,479
61	4	38	42	0	121	121	0	22	22	4	181	185
62	546	1,029	1,575	935	1,815	2,750	350	641	991	1,831	3,485	5,316
63	249	201	450	253	295	548	92	136	228	594	632	1,226
64	110	9	119	229	25	254	102	8	110	441	42	483
65	90	120	210	351	432	783	107	124	240	548	676	1,224
66	140	155	295	5	2	7	2	4	6	147	161	308
67	305	106	411	1,091	356	1,447	347	88	426	1,743	550	2,293
68	115	32	147	541	65	606	100	65	170	756	162	918
69	170	12	182	648	59	707	206	16	224	1,024	87	1,111
70	1	7	8	32	22	54	2	3	5	35	32	67
71	415	3	418	1,190	4	1,194	365	1	361	1,970	8	1,978
72	335	22	357	565	34	599	170	37	205	1,070	93	1,163
73	85	90	175	255	265	520	97	77	174	437	432	869
74	10	188	198	50	900	950	9	199	208	69	1,287	1,356
75	8	228	236	27	570	597	9	175	184	44	973	1,017
76	87	7	94	255	3	258	87	5	92	429	15	444
77	762	15	777	1,470	17	1,487	393	38	431	2,625	70	2,695
78	255	0	255	1,061	0	1,061	178	1	179	1,494	1	1,495
79	0	2	2	2	2	4	2	0	2	4	4	8
80	8	0	8	0	0	0	0	0	0	8	0	8
81	389	6	395	1,102	6	1,108	323	4	327	1,814	16	1,830
82	193	3	196	358	5	363	104	6	110	655	14	669
83	89	3	92	275	2	277	94	5	99	458	10	468
84	47	10	57	39	0	39	26	1	27	112	11	123
85	15	25	40	15	29	44	14	12	26	44	66	110
96	0	8	8	0	2	2	0	3	3	0	13	13
97	2	11	13	0	5	5	0	0	0	2	16	18
98	4	17	21	3	6	9	0	10	10	7	33	40
100	0	130	130	0	76	76	0	25	25	0	231	231
TOTAL	8,901	6,278	15,179	13,636	10,830	24,466	4,584	3,887	8,471	27,121	20,995	48,116

TABLE No. 19. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

East and West Bound Interurban Passenger Traffic on Key System Transit Company Transbay Lines—December 12, 1929, Between San Francisco and East Bay Cities

East Bound				West Bound			
Time leaving San Francisco Ferry Building	Number of passengers	Time leaving San Francisco Ferry Building	Number of passengers	Time leaving Key Pier	Number of passengers	Time leaving Key Pier	Number of passengers
6.00 a.m.	40	3.00 p.m.	289	6.00 a.m.	137	3.00 p.m.	179
6.20 a.m.	28	3.20 p.m.	317	6.20 a.m.	177	3.20 p.m.	196
6.40 a.m.	64	3.40 p.m.	394	6.40 a.m.	343	3.40 p.m.	224
7.00 a.m.	229	4.00 p.m.	408	7.00 a.m.	887	4.00 p.m.	212
7.20 a.m.	184	4.20 p.m.	573	7.20 a.m.	1,699	4.20 p.m.	203
7.40 a.m.	241	4.40 p.m.	866	7.40 a.m.	1,586	4.40 p.m.	218
8.00 a.m.	326	5.00 p.m.	1,671	8.00 a.m.	2,727	5.00 p.m.	326
8.20 a.m.	176	5.15 p.m.	2,850	8.20 a.m.	2,698	5.20 p.m.	355
8.40 a.m.	133	5.30 p.m.	2,103	8.40 a.m.	1,175	5.35 p.m.	270
9.00 a.m.	95	5.45 p.m.	1,683	9.00 a.m.	638	5.50 p.m.	196
9.20 a.m.	120	6.00 p.m.	954	9.20 a.m.	465	6.05 p.m.	158
9.40 a.m.	109	6.20 p.m.	703	9.40 a.m.	333	6.20 p.m.	137
10.00 a.m.	119	6.40 p.m.	387	10.00 a.m.	391	6.40 p.m.	91
10.20 a.m.	105	7.00 p.m.	252	10.20 a.m.	367	7.00 p.m.	102
10.40 a.m.	164	7.20 p.m.	251	10.40 a.m.	329	7.20 p.m.	133
11.00 a.m.	148	7.40 p.m.	185	11.00 a.m.	293	7.40 p.m.	133
11.20 a.m.	168	8.00 p.m.	256	11.20 a.m.	295	8.00 p.m.	78
11.40 a.m.	151	8.40 p.m.	343	11.40 a.m.	287	8.20 p.m.	85
12.00 m.	193	9.20 p.m.	447	12.00 m.	260	9.00 p.m.	155
12.20 p.m.	190	10.00 p.m.	471	12.20 p.m.	272	9.40 p.m.	185
12.40 p.m.	154	10.40 p.m.	447	12.40 p.m.	287	10.20 p.m.	198
1.00 p.m.	118	11.20 p.m.	364	1.00 p.m.	225	11.00 p.m.	240
1.20 p.m.	227	12.00 m.	244	1.20 p.m.	290	11.40 p.m.	141
1.40 p.m.	158	1.00 a.m.	240	1.40 p.m.	228	12.20 a.m.	125
2.00 p.m.	205			2.00 p.m.	208		
2.20 p.m.	175			2.20 p.m.	212		
2.40 p.m.	277	Total	*20,995	2.40 p.m.	194	Total	21,343

*Includes 21 picked up at Key System Pier.

TABLE No. 20. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

East and West Bound Interurban Passenger Traffic By Hours On December 12, 1929, Between San Francisco and East Bay Cities. Key System Transit Company and Southern Pacific Company Combined

Period	Number of passengers		
	Eastbound	Westbound	Total
From 5 a.m. to 6 a.m.		215	215
From 6 a.m. to 7 a.m.	675	2,980	3,655
From 7 a.m. to 8 a.m.	1,870	12,741	14,611
From 8 a.m. to 9 a.m.	1,307	11,067	12,374
From 9 a.m. to 10 a.m.	792	2,618	3,410
From 10 a.m. to 11 a.m.	937	2,101	3,038
From 11 a.m. to 12 m.	1,131	1,822	2,953
From 12 m. to 1 p.m.	1,192	1,573	2,765
From 1 p.m. to 2 p.m.	1,251	1,568	2,819
From 2 p.m. to 3 p.m.	1,586	1,411	2,997
From 3 p.m. to 4 p.m.	2,317	1,428	3,745
From 4 p.m. to 5 p.m.	4,338	1,620	5,958
From 5 p.m. to 6 p.m.	18,596	2,553	21,149
From 6 p.m. to 7 p.m.	4,546	996	5,542
From 7 p.m. to 8 p.m.	1,462	705	2,167
From 8 p.m. to 9 p.m.	1,100	367	1,467
From 9 p.m. to 10 p.m.	1,338	688	2,026
From 10 p.m. to 11 p.m.	1,613	471	2,084
From 11 p.m. to 12 m.	1,122	846	1,968
From 12 m. to 1 a.m.	536	280	816
From 1 a.m. to 2 a.m.	407	48	455
Totals	48,116	48,098	96,214

TABLE No. 21. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

East and West Bound Vehicular Traffic By Hours on December 17, 1929, Between San Francisco and East Bay Cities By Southern Pacific-Golden Gate Ferries, Ltd.

Period	Number of vehicles		
	Eastbound	Westbound	Total
From 6 a.m. to 7 a.m.	100	82	182
From 7 a.m. to 8 a.m.	147	269	416
From 8 a.m. to 9 a.m.	187	390	577
From 9 a.m. to 10 a.m.	437	417	854
From 10 a.m. to 11 a.m.	361	365	726
From 11 a.m. to 12 m.	335	333	668
From 12 m. to 1 p.m.	256	299	555
From 1 p.m. to 2 p.m.	242	295	537
From 2 p.m. to 3 p.m.	317	340	657
From 3 p.m. to 4 p.m.	300	424	724
From 4 p.m. to 5 p.m.	510	453	963
From 5 p.m. to 6 p.m.	504	385	889
From 6 p.m. to 7 p.m.	366	243	609
From 7 p.m. to 8 p.m.	172	229	401
From 8 p.m. to 9 p.m.	125	130	255
From 9 p.m. to 10 p.m.	172	147	319
From 10 p.m. to 11 p.m.	194	182	376
From 11 p.m. to 12 m.	190	140	330
From 12 m. to 1 a.m.	118	87	205
From 1 a.m. to 2 a.m.	70	30	100
From 2 a.m. to 3 a.m.	22	22	44
From 3 a.m. to 4 a.m.	19	20	39
From 4 a.m. to 5 a.m.	20	18	38
From 5 a.m. to 6 a.m.	22	45	67
Totals	5,186	5,345	10,531

TABLE No. 22. SAN FRANCISCO BAY BRIDGE TRAFFIC SURVEY

Total Vehicles Carried By Routes and Months During the Year 1929, Between San Francisco and East Bay Cities By Southern Pacific-Golden Gate Ferries, Ltd.

Months	Total vehicles carried					
	San Francisco Ferry Building to Richmond Route	Hyde street San Francisco to Berkeley Route	Mission street to Oakland Pier Route	Foot of Mission street to foot of Broadway, Oakland Pier	Foot of Mission street to Alameda Route	Total all routes
January	5,965	76,548	227,690	2,347	15,791	328,341
February	5,766	76,173	221,836	1,372	15,886	321,033
March	6,774	89,555	247,259	1,289	16,893	361,770
April	6,303	84,895	235,006	1,294	14,824	342,322
May	7,400	93,486	255,242	1,397	16,379	373,904
June	8,358	91,913	251,900	1,442	16,689	370,302
July	9,202	97,404	262,980	1,681	17,026	388,293
August	9,965	109,478	284,429	1,774	19,229	424,875
September	9,231	105,147	271,567	1,232	17,111	404,288
October	7,834	102,411	264,183	1,352	15,722	391,502
November	7,641	104,889	266,994	1,475	15,344	396,343
December	6,962	94,075	269,015	1,422	16,066	387,540
Totals	91,401	1,125,974	3,058,101	18,077	196,960	4,490,513

TABLE No. 23. SAN FRANCISCO BAY BRIDGE TRAFFIC STUDY

Total Vehicles By Days During July and November, 1929, and Totals By Routes for These Months Carried Between San Francisco and East Bay Cities By the Southern Pacific-Golden Gate Ferries, Ltd.

Day of month and route	Total vehicles carried	
	July	November
1	11,925	11,263
2	11,414	12,553
3	13,147	19,011
4	16,005	10,682
5	11,991	10,260
6	12,064	10,943
7	15,731	10,910
8	11,552	11,863
9	10,692	14,970
10	11,065	20,153
11	11,048	16,362
12	11,523	10,933
13	12,800	10,500
14	17,927	10,430
15	11,668	11,193
16	11,034	15,261
17	11,102	17,899
18	11,163	10,912
19	11,291	10,662
20	13,200	10,723
21	17,583	10,809
22	11,452	12,892
23	10,892	14,079
24	11,570	19,431
25	11,524	10,988
26	11,633	10,730
27	13,264	12,862
28	17,565	21,290
29	11,585	13,268
30	11,173	12,511
31	11,696	
Totals	388,279	396,343
San Francisco Ferry Building to Richmond	9,202	7,641
Hyde street, San Francisco, to Berkeley	97,390	104,889
Foot of Mission to Oakland Pier	262,980	266,994
Foot of Mission to foot of Broadway, Oakland	1,681	1,475
Foot of Mission to Alameda	17,026	15,344
Totals	388,279	396,343

TABLE No. 24. ANALYSIS OF TRANSBAY VEHICULAR TRAFFIC SHOWING COMPARISON BETWEEN PRESENT FERRY ROUTES AND BRIDGE LOCATION No. 5

Average to San Francisco Traffic Center

Item	East Bay Zone (1)	Per cent of total traffic (2)	Added travel distance, miles (3)	Added driving distance, miles (4)	Saving in time, minutes (5)	Added car operating cost per trip (6)
Group A (north of Berkeley Ferry)	64	1.81				
	69	.71				
	70	.26				
	85	1.91				
	96	9.55				
		14.24	7.63	12.03	—.35	$0.4812
Group B (East of Berkeley Ferry)	62	8.04				
	65	.95				
	66	1.23				
	67	2.54				
	68	1.43				
		14.19	6.48	9.98	4.25	.3992
Group C (North and West Oakland)	50	.34				
	51	1.30				
	57	2.49				
	58	.80				
	59	1.64				
	60	2.89				
	61	.32				
	63	.92				
	75	2.82				
	98	1.78				
		15.30	6.21	9.71	8.56	.3884
Group D (Central Oakland)	52	24.36				
	53	5.82				
	55	2.28				
	56	2.23				
	74	1.52				
		36.21	5.80	9.30	11.36	.3720
Group E (East Oakland)	72	1.81				
	73	1.36				
	76	.63				
	77	2.16				
	81	1.16				
	82	.87				
	83	1.07				
	84					
	97	6.61				
		15.67	5.80	9.30	11.37	.3720
Group F (Alameda)	54	1.47				
	71	1.88				
	78	.90				
	79	.02				
	80	.12				
		4.39	2.77	6.07	17.99	.2428

TABLE No. 25. ANALYSIS OF TRANSBAY VEHICULAR TRAFFIC SHOWING GROUPING OF SAN FRANCISCO TRAFFIC ORIGIN

	Zone number (1)	Per cent of total traffic (2)	Total per cent
Group X (Northern San Francisco)	1	9.14	
	2	5.70	
	3	24.17	
	4	6.79	
	5	13.67	
	6	3.25	
	7	.87	
	8	3.30	
	9	2.35	
	10	4.51	
	19	2.29	
	20	.57	
	21	3.23	
	28	.31	
			80.15
Group Y (Southern San Francisco)	11	3.33	
	12	5.79	
	13	.72	
	14	.51	
	15	.42	
	16	.90	
	17	.57	
	18	.87	
	22	.21	
	23	.72	
	24	.20	
	25	.66	
	26	.78	
	27	.02	
	46	2.10	
	47	.25	
	48	1.62	
	49	.18	
			19.85
			100.00

The following reports were reviewed in preparing traffic data:

Report of Board of Engineers—Transbay Bridge, San Francisco.

Report to Intercities Bridge Company—by Thompson and Butler, Consulting Engineers.

A Report on The Street Traffic Control Problem of San Francisco—by Miller McClintock.

Major Streets, San Francisco—Report to the San Francisco Traffic Survey Committee—by Bartholomew and Associates.

A Major Street Plan for Oakland, California—Major Highway and Traffic Committee of One Hundred—by Bartholomew and Associates.

Traffic Studies and Reports—Engineering Department, California Railroad Commission.

Annual Reports—Delaware River Bridge Joint Commission of States of Pennsylvania and New Jersey.

Annual Reports—New York State Bridge and Tunnel Commission.

Operating Statements of Key System Transit Company and Southern Pacific Company relative to Interurban Trains and Transbay Ferry Operations.

I-B. Water Borne Traffic.

1. **Ocean Going Traffic.** As before stated, a rather comprehensive survey of water borne traffic prior to and including 1926 is given in the 1927 report of the Board of Engineers. Full data are given on tonnage entering San Francisco Bay, heights of masts, funnels, etc.

The general trend of ship construction since 1927 indicates that the tendency is not to increase the heights of masts and funnels over those given in the 1927 report. In order to give the Commission a picture of the increase in water borne traffic, reference is made to the following tables:

TABLE No. 26. OCEAN SHIPPING THROUGH GOLDEN GATE

Year	Arrivals		Departures		Total	
	Number of vessels	Net registered tonnage	Number of vessels	Net registered tonnage	Number of vessels	Net registered tonnage
1914	5,857	7,449,715	5,870	7,345,360	11,727	14,795,075
1915	5,717	7,484,683	5,912	7,650,706	11,629	15,135,389
1916	5,570	7,230,510	5,631	7,230,002	11,201	14,460,512
1917	5,352	7,075,553	5,417	7,139,168	10,769	14,224,721
1918	4,561	5,440,473	4,566	5,691,490	9,127	11,131,963
1919	4,617	6,047,425	4,696	6,214,244	9,313	12,261,669
1924	6,486	14,273,246	6,529	14,070,942	13,015	28,344,188
1925	6,655	15,251,304	6,726	15,168,898	13,381	30,420,202
1926	6,836	15,646,656	6,878	15,770,794	13,714	31,417,450
1927	7,045	16,876,841	7,135	16,554,456	14,180	33,431,297
1928	7,555	18,110,440	7,705	17,895,006	15,260	36 005,446
1929	7,806	19,592,704	7,959	19,537,605	15,765	39,130,309

Source: San Francisco Chamber of Commerce.

TABLE No 27. WATER BORNE COMMERCE OF SAN FRANCISCO BAY

1926

	Short tons cargo	Value in dollars
Foreign	3,744,289	$397,213,309
Intercoastal	2,369,405	260,000,000
Non-contiguous	1,679,898	126,500,000
Coastwise	21,000,000	900,000,000
Inland waterways	9,950,000	675,000,000
Totals	38,775,592	$2,358,713,309

1928

	Short tons cargo	Value in dollars
Foreign	5,312,410	$521,471,225
Intercoastal	2,065,485	103,908,877
Non-contiguous	1,376,960	69,272,515
Coastwise	19,507,391	981,360,528
Inland waterways	12,756,773	581,738,105
Totals	41,019,019	$2,257,747,250

Source: Annual Report of the U. S. Shipping Board, 1928; Chief of Engineers, U. S. Army, Annual Report for 1929, detailed 1928 statistics.

TABLE No. 28. FOREIGN TRADE OF SAN FRANCISCO BAY

	Exports	Imports	Total
1903-1913 (average)	$43,749,230	$54,994,185	$98,743,415
1921	129,110,857	97,129,057	226,239,914
1922	145,098,619	170,814,723	315,913,342
1923	160,432,622	166,776,496	327,209,118
1924	173,441,076	146,335,252	319,776,328
1925	183,013,778	197,375,410	380,389,188
1926	187,125,566	210,087,743	397,213,309
1927	174,555,772	200,004,238	374,560,010
1928	201,440,402	198,301,326	399,741,728
1929	206,206,840	212,672,215	418,879,055

Source: Records of the Collector of Customs.

TABLE No. 29. OAKLAND HARBOR

Section included: From San Francisco Bay to San Leandro Bay, a distance of about seven miles. The commerce includes foreign, coastwise, intraport and ferry traffic.

	Tons	Value	Passengers
1925	2,766,966	$173,889,886	45,347,215
1926	3,914,173	209,647,755	45,219,078
1927	3,217,897	200,325,445	[1] 44,931,609
1928	4,334,515	262,582,072	43,775,378
1929	5,798,889	326,660,368	45,442,695

[1] Includes 65,198 Estuary passengers.
Source: Chief Engineer's Report, San Francisco District, 1929.

TABLE No. 30. 1929 FERRY TRAFFIC, OAKLAND HARBOR

	Freight, short tons	Value (approximately)	Passengers	Automobiles	Trucks and other vehicles
General ferry traffic	432,401	Not known	45,352,417	4,366,321	32,163
Railroad car ferry traffic	1,518,099	Not known	63,946	41	----------
Totals	1,950,500	----------	45,416,363	4,366,362	32,163

TABLE No. 31. OAKLAND HARBOR, 1929

Classes of commodities	Foreign		Coastwise		Intraport		Total foreign and domestic, tons
	Imports, tons	Exports, tons	Receipts	Shipments	Receipts	Shipments	
Animals and animal products	2,762	2,983	28,316	107,067	60,361	60,588	262,077
Vegetable food products	114,286	124,473	97,457	315,710	136,899	17,308	806,133
Other vegetable products	586	----------	1,032	645	541	39	2,843
Textiles	----------	1,321	5,910	2,724	109	100	10,164
Chemicals	3,203	164	25,027	27,894	5,477	2,915	64,680
Wood and paper	7,430	13,946	1,508,398	25,037	14,822	29,682	1,599,315
Nonmetallic minerals	43,606	1,859	955,113	50,598	685,473	699,375	2,436,024
Ores, metals and manufactures of	42,731	261	171,527	44,232	6,949	5,645	270,445
Machinery and vehicles	296	2,785	19,606	14,946	983	1,512	40,128
Unclassified	13,255	34,885	39,685	36,264	30,368	152,623	307,080
Totals	228,155	182,677	2,852,071	625,117	941,082	969,787	5,798,889

TABLE No. 32. TRIPS AND DRAFTS OF VESSELS—OAKLAND HARBOR, 1929

Draft (feet)	Inbound							
	Steamers	Motor vessels	Sailing vessels	Yachts and fishing boats	Lighters	Steam and gasoline schooners	Steam, gas and diesel tugs	Total
Over 30 feet	7							7
28 to 30	43	12						55
26 to 28	114	37						151
24 to 26	189	55			8			252
22 to 24	253	55				3		311
20 to 22	463	49			5	31		548
18 o 20	842	42	1		2	71		958
16 to 18	936	28	1		2	133		1,100
14 to 16	1,116	30	1		11	88	111	1,357
12 to 14	417	29	1	14	111	74	436	1,082
10 to 12	286	6		29	35	92	395	843
8 to 10	179	6	1	39	1,677	115	1,216	3,233
6 to 8	286	590		49	3,316	2	5,326	9,569
Less than 6 feet	252	131		43	6,091	1,950	6,138	14,605
Totals	5,383	1,070	5	174	11,258	2,559	13,622	34,071
Total net registered tonnage	8,928,446	1,269,177	6,497	4,813	2,569,481	427,538	211,798	13,417,750
Passengers:								
Excursion								
Regular	2,613	34	519					3,166
Ferry (see grand total below)								
Grand total	10,766	2,140	10	348	22,516	5,118	27,244	68,142
Net registered tonnage	17,856,892	2,538,354	12,944	9,626	5,138,962	854,076	423,596	26,835,500
Passengers:								
Regular	6,332							
Ferry	45,416,363							

TABLE No. 33. TRIPS AND DRAFTS OF VESSELS—OAKLAND HARBOR, 1929

Draft (feet)	Outbound							
	Steamers	Motor vessels	Sailing vessels	Yachts and fishing boats	Lighters	Steam and gasoline schooners	Steam, gas and diesel tugs	Total
Over 30 feet	7							7
28 to 30	41	13						54
26 to 28	124	42						166
24 to 26	157	59			1			217
22 to 24	207	42				2		251
20 to 22	357	40				20		417
18 to 20	694	35	1			63		793
16 to 18	892	38	1		2	117		1,050
14 to 16	1,207	36	1		17	77	117	1,455
12 to 14	554	32		14	73	105	438	1,216
10 to 12	372	7	1	29	60	113	399	981
8 to 10	211	5		38	1,694	110	1,204	3,262
6 to 8	310	590	1	52	3,322	3	5,326	9,604
Less than 6 feet	250	131		41	6,089	1,949	6,138	14,598
Totals	5,383	1,070	5	174	11,258	2,559	13,622	34,071
Total net registered tonnage	8,928,446	1,269,177	6,497	4,813	2,569,481	427,538	211,798	13,417,750
Passengers:								
Excursion								
Regular	2,613	34	519					3,166
Ferry								

A study of records has been made to determine the points at which ships dock. The total volume of shipping has been divided into zones, each zone having as its northern boundary the respective location of each bridge location being considered, the object being to determine the amount of shipping which would pass under each bridge.

Vessels were counted only once at their originally assigned berths. Movements between piers were not counted. Launches and other small craft were counted as one arrival at their regular assigned berth irrespective of the number of piers they touched during a day. The tabulation of vessels includes barges, lighters and river steamers but not ferryboats. Vessels of the United States Government not actually docking were not counted.

The results are noted under the following headings:

First Zone—

South of 16th Street Pier (Location No. 2).

Arriving:	2,710	vessels
	2,204,037	net tonnage
	1,211,181	cargo tonnage

Second Zone—

South of Pier 34 (Location No. 1).

Arriving:	8,117	vessels
	7,678,302	net tonnage
	3,337,423	cargo tonnage

Third Zone—

South of Pier 32 (Location No. 1-A).

Arriving:	8,409	vessels
	8,892,169	net tonnage
	3,699,776	cargo tonnage

Fourth Zone—

South of Pier 22 (Location No. 4).

Arriving:	9,887	vessels
	11,954,563	net tonnage
	5,139,146	cargo tonnage

Fifth Zone—

South of Pier 21 (Location No. 3).

Arriving:	22,633	vessels
	17,318,580	net tonnage
	* 7,403,531	cargo tonnage

A chart showing the distribution of shipping at each dock north of Pier 21, giving the number of vessels and the net tonnage involved is shown on Plate 36.

Reference is made to Plate No. 54 showing the designation of the various lines.

* Includes cargo tonnage of ferryboats.

2. Ferries.

(a) General. Reference is again made to the 1927 Engineer's Report (pages 43 and 44) for statistics and subject matter on the various ferry lines operating on San Francisco Bay. Also to map showing the approximate lines over which each of these ferry lines operate.

A tabulation of ferry passenger traffic up to and including 1926 is given on page 45 of the 1927 Engineer's Report. Likewise a tabulation of vehicular traffic is given on page 46. Similar tabulations are completed up to and including 1929 in Section I of this report.

It will be noted that the total rail passengers, viz, ferry passengers, predicted in the 1927 report, for 1929, was 38,701,000. The actual rail passengers given in Section I for 1929 are 35,923,855, an actual decrease of approximately 7.2 per cent below the predicted traffic.

It will be further noted that the 1927 prediction for vehicular traffic was, for 1929, 3,537,565 vehicles and 8,243,000 passengers. An actual count shows 4,490,513 cars and 10,174,028 passengers for 1929 or an increase over the 1927 prediction of 27 per cent in vehicles and 23½ per cent in passengers.

(b) Movements between San Francisco and East Bay by ferries. Tables Nos. 34 and 35 set forth for typical week-day excluding Saturday and Sunday, the total number of trips for ferryboat movements by routes and by hours. Plate 37 sets forth graphically the same data, showing the movements by passenger ferryboats, automobile ferryboats and freight ferry, showing a maximum of approximately 45 ferryboat movements per hour between the San Francisco water front and the East Bay.

The number of passenger ferryboat movements has remained practically constant for a number of years and may be expected to remain so, since this traffic does not appear to be increasing. Vehicular ferry movements have increased quite rapidly in the last six years. The exact schedule for 1925 or 1927 is not available. However, in 1925, neither the Alameda nor Berkeley ferries were in operation and a materially smaller number of automobile ferry boats was in use. The number of trips per hour in 1925 for passenger, vehicular and freight ferries probably did not exceed 30 while at present there are 45 such trips. The peak of ferry boat movements occurs normally on a Sunday or holiday with resultant greater vehicular ferryboat operation, especially on the Oakland-Seventh street and Berkeley Pier routes. The schedule indicated in Table 35 shows for the Berkeley and Seventh street routes a maximum total of 16 per hour for typical week days. Under peak operation the number increases to 18 for Seventh street and 8 for Berkeley, making a total of 26 per hour as against 16 during the week. There is one less Key System movement and one less Broadway movement on holidays so that the maximum ferry movement at this time would total between 50 and 55 per hour. Of these total movements, approximately 40 to 45 are concentrated within the frontage at or near the Ferry Building, where greatest congestion occurs.

TABLE No. 34. NUMBER OF OAT TRIPS ON SAN FRANCISCO BAY BETWEEN SAN FRANCISCO AND EAST BAY POINTS

On Basis of Present Schedules for "Monday to Friday" Period. Number of Departures From "On the Hour" to "59 Minutes Past the Hour"—To and From San Francisco

Departures between	Passenger					
	Santa Fe	Key System	Southern Pacific		Western Pacific	Total
			Oakland Pier	Alameda Pier		
6 a.m. and 7 a.m.	1	6	7	4		18
7 a.m. and 8 a.m.	1	6	6	4	1	18
8 a.m. and 9 a.m.		6	6	4		16
9 a.m. and 10 a.m.	1	6	6	4		17
10 a.m. and 11 a.m.	1	6	6	4	1	18
11 a.m. and 12 m.		6	6	4		16
12 m. and 1 p.m.		6	6	4		16
1 p.m. and 2 p.m.		6	6	4		16
2 p.m. and 3 p.m.		6	6	4		16
3 p.m. and 4 p.m.		6	6	4	1	17
4 p.m. and 5 p.m.		6	6	4		16
5 p.m. and 6 p.m.	1	7	6	5		19
6 p.m. and 7 p.m.	1	7	6	4		18
7 p.m. and 8 p.m.		6	4	4		14
8 p.m. and 9 p.m.		4	2	3	1	10
9 p.m. and 10 p.m.	1	3	4	2		10
10 p.m. and 11 p.m.	1	3	2	3		9
11 p.m. and 12 m.		3	4	3		10
12 m. and 1 a.m.		2	2	2		6
1 a.m. and 2 a.m.		1	1			2
2 a.m. and 3 a.m.			1			1
Totals	8	102	99	70	4	283

TABLE No. 35. NUMBER OF BOAT TRIPS ON SAN FRANCISCO BAY BETWEEN SAN FRANCISCO AND EAST BAY POINTS

On Basis of Present Schedules for "Monday to Friday" Period. Number of Departures From "On the Hour" to "59 Minutes Past the Hour"—To and From San Francisco

Departures between	Vehicular					Freight car			Total
	Southern Pacific-Golden Gate Ferries								
	Richmond Route	Berkeley Route	7th Street Route	Broadway Route	Alameda Route	Santa Fe[1]	Southern Pacific	Western Pacific[2]	
6 a.m. and 7 a.m.	2	3	6		4	2	1	1	19
7 a.m. and 8 a.m.	2	6	8	1	4	2	1	1	25
8 a.m. and 9 a.m.	2	6	8	2	4	2		1	25
9 a.m. and 10 a.m.	4	6	8	1	4		1	1	25
10 a.m. and 11 a.m.	2	5	8	1	4				20
11 a.m. and 12 m.	2	6	1	2	4		1		25
12 m. and 1 p.m.	2	6	10	1	4		1		24
1 p.m. and 2 p.m.	2	6	10	1	4		1		24
2 p.m. and 3 p.m.	4	6	10	1	4				25
3 p.m. and 4 p.m.	2	6	10	2	4	2	1		27
4 p.m. and 5 p.m.	2	6	10	1	4	2			25
5 p.m. and 6 p.m.	2	6	10	1	3	2	1	1	26
6 p.m. and 7 p.m.	2	6	10		4	2		2	26
7 p.m. and 8 p.m.	4	6	9		4	2	2	3	30
8 p.m. and 9 p.m.	2	6	6		3	2	1	2	22
9 p.m. and 10 p.m.	1	4	6		2	2			15
10 p.m. and 11 p.m.	1	4	6		2		1		14
11 p.m. and 12 m.	2	4	6		2				14
12 m. and 1 a.m.		4	5		1		1		11
1 a.m. and 2 a.m.		3	4						7
2 a.m. and 3 a.m.		2	2				1		5
3 a.m. and 4 a.m.		2	2				1		5
4 a.m. and 5 a.m.		2	2						4
5 a.m. and 6 a.m.		2	2				1		5
Totals	40	113	168	14	65	20	16	12	448

[1] Spread by hours is arbitrary, based on peaks during 6:30 to 9:00 a.m. and 3:30 to 9:00 p.m.
[2] Spread arbitrary.

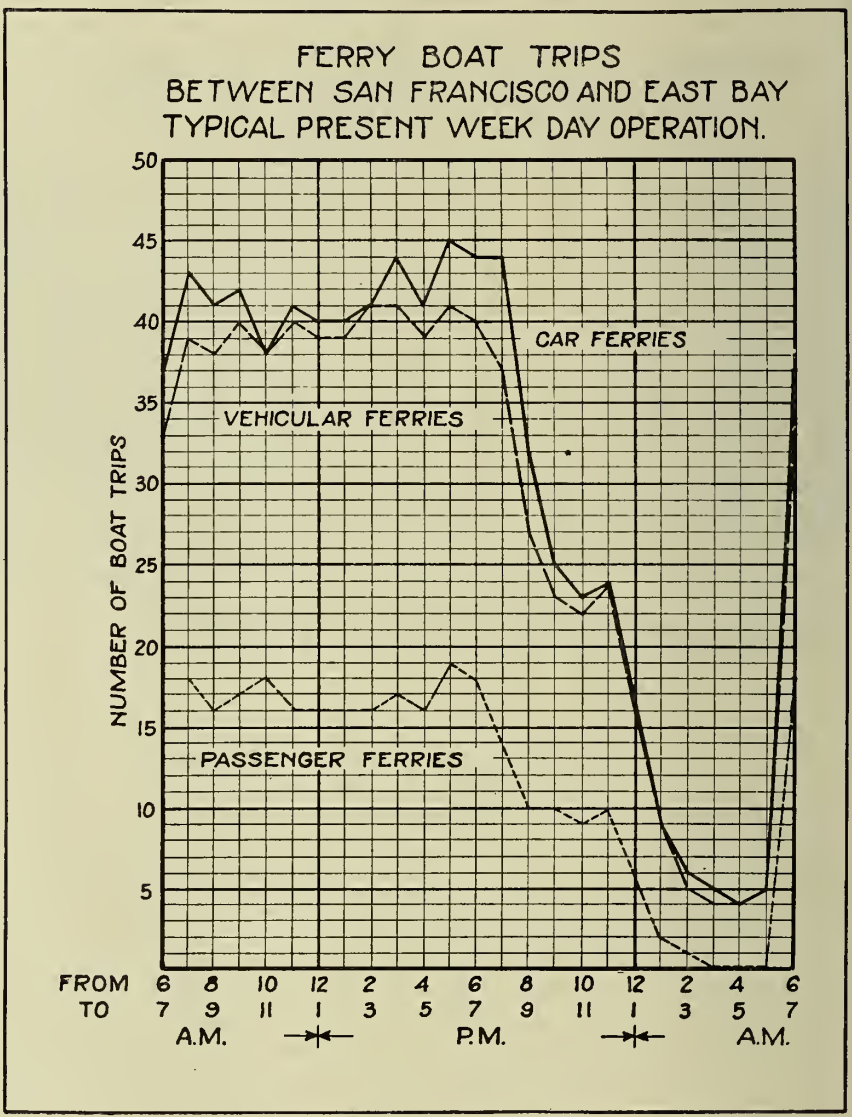

FERRY BOAT TRIPS
BETWEEN SAN FRANCISCO AND EAST BAY
TYPICAL PRESENT WEEK DAY OPERATION.
NUMBER OF BOAT TRIPS
50
45
40
35
30
25
20
15
10
5
CAR FERRIES
VEHICULAR FERRIES
PASSENGER FERRIES
FROM 6 8 10 12 2 4 6 8 10 12 2 4 6
TO 7 9 11 1 3 5 7 9 11 1 3 5 7
A.M. P.M. A.M.

PLATE No. 9

SECTION II

BORINGS AND FOUNDATION DATA

1. General.

Prior to the recent borings taken by this department, at the request of the San Francisco Bay Bridge Commission, there was (with two exceptions) no definite knowledge as to what might be encountered in the way of suitable foundation material in the bay area between San Francisco and Oakland. One exception mentioned refers to two holes drilled by the Inter-Cities Bridge Company on the proposed private bridge project between Goat Island and Telegraph Hill. The other exception was the knowledge that Rincon Rock (a former rock ridge known as Inner and Outer Rock, having its outer edge approximately 2200 feet outside of Pier 34) had been removed by blasting to a depth of some 40 feet below low water.

It was known that piles along the water front used in dock construction, except in the vicinity of Rincon Reef, could be driven to very great depth in apparently very soft material. The wide expanse of the bay across which any bridge must pass was unprospected as far as depths to suitable foundation was concerned. This fact was particularly noted by Messrs. Talbot, Ridgeway and Galloway, in their 1927 report. No intelligent cost estimate could be arrived at until such borings were made, and even the possibility of building a bridge could not be determined on any complete line.

Confronted by this lack of any definite knowledge as to what might be expected in the nature of substrata, and by a rather limited amount of funds, it was decided after some study to follow this procedure:

First: To prospect the various lines by means of a high pressure jet and to determine the depth beyond which such a jet could not penetrate.

Second: After having determined by means of the jet whether or not any of the prospective lines gave promise of affording a suitable foundation at practical depths; then to determine by means of a core drill the nature and character of the underlying strata which the jet could not penetrate.

The jetting operation would be comparatively fast. For the funds available we would be able to put down several times as many holes as could be drilled by a core drill. By use of the jet it would be at once discovered at comparatively small expense whether or not the depth justified core drilling.

The unknown conditions which might be encountered and great variation in methods of procedure which might be necessary during the progress of drilling made it impossible to ask contractors to bid on a footage basis.

2. Advertisement and award of boring contract.

Specifications were prepared upon a daily equipment rental basis, including specified minimum operating crews. Proposals were requested from several contracting firms equipped to do this type of work:

Bids were received on January 7, 1930, as follows:

Healy-Tibbitts	$25,643 69
Ben Gerwick	28,341 50
Butte Construction Co.	65,599 00
Duncanson-Harrelson Co.	26,829 30

The bid of Healy-Tibbitts was irregular and was accompanied by an insufficient certified check. For these reasons the bid of Healy-Tibbitts was rejected and the second bidder, The Duncanson-Harrelson Co., was awarded the contract.

3. Progress of boring contract.

The first jet boring was started on January 30, 1930, on the Rincon-Alameda line. Drilling operations continued with but very little interruption to the final completion on June 26, 1930. The original estimate contemplated that for the funds available we would be able to put down not more than 25 jet borings and five cored holes.

Fortunately the low bidder, the Duncanson-Harrelson Co., had acquired extensive experience in similar work. The equipment furnished was excellent and, by efficient methods and close cooperation between the contractor and resident engineer, we were able to put down forty-one jet borings and four core drilled holes.

4. Final cost.

The final cost of the borings, which includes all administrative and engineering charges, is as follows:

JET BORINGS

Total cost		$16,772.35
Total number feet jetted	7,897.1	
*Cost per lineal foot		$2.124

DIAMOND DRILL BORINGS

Total cost		$15,375.13
Total number feet drilled	837.4	
*Cost per lineal foot		$18.36

* Measured from mean lower low water.

5. Equipment.

(a) *Drill Barge.*

The drill barge had an over-all length of 110 feet, beam 32 feet, and depth 8 feet.

The barge was equipped with 76′ 0″ pile driver leads with an outrigger attachment. At the bottom a timber yoke was cantilevered out to support the drill cage and act as a guide to provide for the rise and fall of the tide.

An $8\frac{1}{4}$″ x 10″ double drum Lidgerwood hoist was used to handle the drill cage, casing and sampling pipes.

One triple drum Lambert $7\frac{1}{2}$″ x 10″ hoist and one double drum Murray $6\frac{1}{4}$″ x 12″ hoist, both at the stern of the barge were used in handling the five anchor cables.

Five 5000 pound patent anchors, each with 800 feet of 8/19 plow steel cable, were used in anchoring the barge.

Other miscellaneous barge equipment included:

2 4745 gal. wooden water tanks.
1 7000 gal. steel fuel oil tank.
1 8′ x 19′ office.
1 8′ x 19′ tool house.

1 45 h.p. boiler (Lidgerwood).
1 35 h.p. boiler (American).
1 10″ x 5″ x 10″, 2 cyl. double acting Dow pump.
1 Steam—electric generator.
1 237½ gal. fuel oil tank.
1 4½″ x 3″ x 4″ oil pump (Canton Pump Co.).
1 420 gal. fuel oil tank.
1 9½″ x 10″ single phase Westinghouse compressor.
4 6 volt batteries.
4 Spotlights.

(b) *Oil and Water Barge.*

The water and oil barge had an over-all length of 70 feet, beam 24 feet and depth 8 feet. Other miscellaneous equipment included:

1 Water pump 7½″ x 4½″ x 6″ (Empire-Carpenter).
1 6¼″ x 10″ American hoisting engine.
1 35 h.p. boiler.
1 250 gal. fuel oil tank.
1 7½″ x 12″ Mundy hoisting engine.
1 Stiff-leg derrick with 30′ boom.

A sketch of the drill barges is shown on Plate No. 37 and also by photographs.

(c) *Drill Cage.*

Most of the borings were taken in water in excess of 40 feet deep. The lateral force of the tidal current is so strong (maximum observed velocity 8.8 feet per second) that it prohibits the operation of jet pipe or casing without a supporting column.

A 24″ square latticed steel cage was used. It was made in 20-foot sections with one 10-foot section. Two funnel-shaped guides were provided in each section which served to hold the jet pipe or casing in a steady position. A sketch of the drill cage is shown on Plate No. 10.

In certain locations where the material at the mud line was very soft, the drill cage would keep sinking into the mud. At such locations a spread footing, in the form of wooden sills, was bolted to the cage near the bottom. This provided sufficient area to check successfully such subsidence.

(d) *Drill Platform.*

During diamond drilling operations the drilling could not be done from the barge because of the rocking of the barge and the rise and fall of the tide.

A 12′ x 15′ platform was erected on top of the drill cage which in turn was resting on the mud. The diamond drill was mounted on this platform, which provided a reasonably stable structure from which to drill.

(e) *Diamond Drill.*

The diamond drill machine was a light, portable, gasoline driven machine, mounted on a steel frame with wooden skids. It proved to be a very convenient size, comparatively easy to handle, and most

suitable for the unusual conditions under which the diamond drilling was performed.

(f) *Tug and Launch.*

A 200 h.p. Diesel tug was used to tow the barges from one location to the next. In most cases this provided sufficient power to tow the equipment. However, on several occasions moves had to be made during a tidal phase of considerable range and, at such times, the services of an additional tug had to be made use of in order to cope with the tidal current.

A 25 h.p. gasoline launch with open cock-pit provided transportation to and from the drill barges and carried small equipment and supplies.

(g) *Crew.*

Operations were carried on during five days a week upon an 8-hour day basis. No work was done on Saturdays and Sundays because of the fact that the union labor employed was on a five-day week schedule.

The drill rig crew used in jetting operations consisted of one foreman, one hoisting engineer, and four pile driver laborers.

The diamond drill crew consisted of one foreman, one diamond drill setter, one diamond drill runner, one hoisting engineer, and two laborers. The personnel of the two crews was different, with the exception of the foreman and hoisting engineer.

A watchman was on the barge at all times when the crew was not working.

6. Methods used.

(a) *Locating Borings.*

The various boring sites were plotted on U. S. C. & G. S. Chart No. 5535, scale 1-inch equalling 1666.667 feet and also on a specially prepared map drawn to the scale, one inch equalling one thousand feet. The barge was located at each boring by the three-point method, angles being measured between predetermined points on shore with a sextant. The position was then plotted with a three-arm protractor.

The United States Coast and Geodetic Survey has the location of numerous control points (prominent towers, flagpoles, etc.) throughout the bay area given to thousandths of a second of latitude and longitude. They are also shown on all U. S. C. & G. S. Charts. Coordinates of these points were computed in feet from the given latitude and longitude and the points plotted on the large scale map.

Two sextants and a three-arm protractor were furnished by the U. S. Engineer's Office. The sextant had a small telescope attachment which greatly facilitated its use. A vernier with reading glass attachment made it possible to read angles to fifteen seconds. The nature of the points sighted were such that it was only practical to read angles to the nearest half minute.

For plotting, the three-arm protractor was used. This had a circle graduated in half degrees and was equipped with a vernier and magnifying glass so that angles could be read direct in minutes and estimated to the nearest half-minute of arc.

The maps controlled the accuracy of the location. It is not practicable to compute the probable error of one of our locations when finally made, but we estimate it to be less than one per cent.

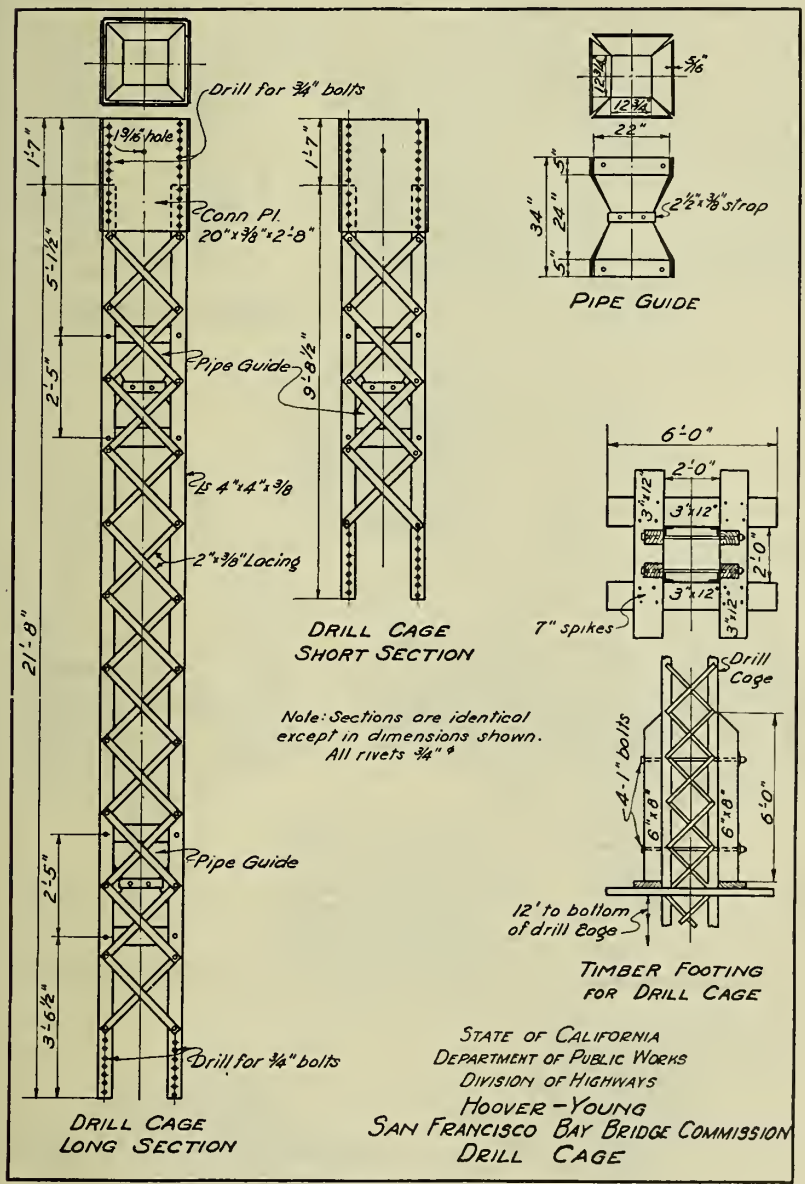

Drill for ¾" bolts
1'-7"
1⅜" hole
Conn Pl. 20"x⅜"x2'-8"
5'-1½"
2'-5"
Pipe Guide
9'-8½"
2L 4"x4"x⅜
2"x⅜" Lacing
21'-8"
2'-5"
Pipe Guide
3'-6½"
Drill for ¾" bolts
DRILL CAGE LONG SECTION
DRILL CAGE SHORT SECTION
Note: Sections are identical except in dimensions shown. All rivets ¾" ϕ
12¾"
12¾"
⅜"
2'-2"
5"
34"
24"
5"
2½"x⅜" strap
PIPE GUIDE
6'-0"
2'-0"
3"x12"
3"x12"
3"x12"
3"x12"
2'-0"
7" spikes
Drill Cage
4-1" bolts
6"x8"
6"x8"
6'-0"
12' to bottom of drill cage
TIMBER FOOTING FOR DRILL CAGE
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
DRILL CAGE

PLATE No. 10

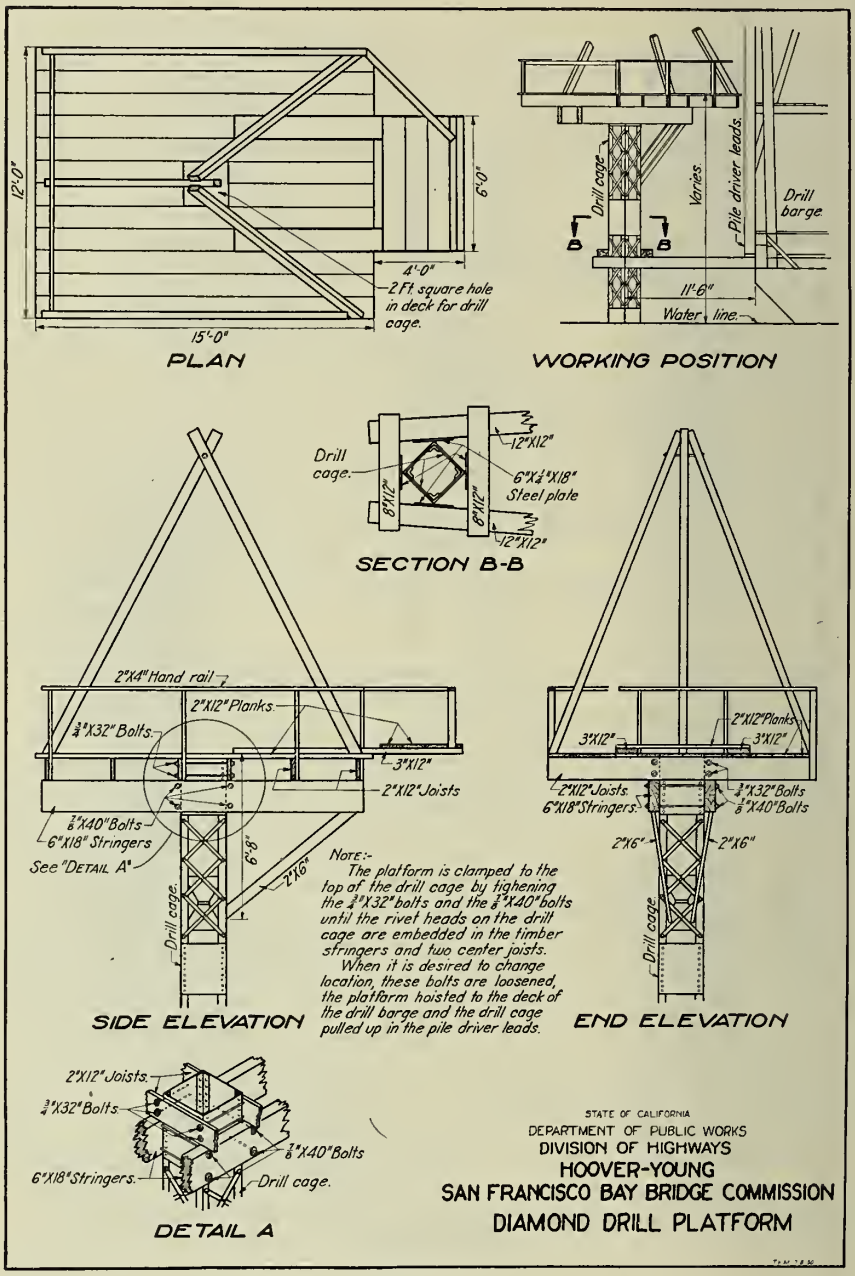

12'-0"
6'-0"
4'-0"
2 Ft. square hole in deck for drill cage.
15'-0"
PLAN
Drill cage.
Varies.
Pile driver leads.
Drill barge.
B
B
11'-6"
Water line.
WORKING POSITION
Drill cage.
12"X12"
6"X1/4"X18" Steel plate
8"X12"
8"X12"
12"X12"
SECTION B-B
2"X4" Hand rail
2"X12" Planks
3/4"X32" Bolts
3"X12"
2"X12" Joists
7/8"X40" Bolts
6"X18" Stringers
See "DETAIL A"
6'-8"
2"X6"
Drill cage.
SIDE ELEVATION
2"X12" Planks
3"X12"
3"X12"
2"X12" Joists
6"X18" Stringers
7/8"X32" Bolts
7/8"X40" Bolts
2"X6"
2"X6"
Drill cage.
END ELEVATION
NOTE:-
The platform is clamped to the top of the drill cage by tightening the 3/4"X32" bolts and the 7/8"X40" bolts until the rivet heads on the drill cage are embedded in the timber stringers and two center joists.
When it is desired to change location, these bolts are loosened, the platform hoisted to the deck of the drill barge and the drill cage pulled up in the pile driver leads.
2"X12" Joists.
3/4"X32" Bolts
7/8"X40" Bolts
6"X18" Stringers.
Drill cage.
DETAIL A
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
DIAMOND DRILL PLATFORM

PLATE No. 11

(b) *Anchoring Barges.*

When locating a point where a boring was to be made, the barges were towed approximately to the point and tentative readings were taken with the sextants and plotted. If this proved to be too far from the point, the tug pilot was given the direction and distance to go in order to reach the desired location. This process was again repeated until the barges were spotted four or five hundred feet upstream from the boring site. The bow anchor was then lowered, the anchor line paid out and the barges were allowed to drift with the tidal current to the desired point, as near as could be judged. Another set of sextant readings was then taken and, if the barge was within 100 feet of the point, the four breast anchors were placed. Each breast anchor was lashed to the small oil and water barge, towed to its position, about four or five hundred feet out from the drill barge, at an angle of about 135 degrees from each side of the drill barge, and dropped. The final adjustment of the barge into position was then made by taking in or paying out on the anchor lines and all anchor lines were then drawn taut by the hoisting engines. Final sextant readings were then taken, plotted and recorded, and drilling operations began.

A pennant line was fastened to the flukes of all anchors. A $\frac{5}{8}$" cable about 150 feet long was spliced to the pennant. The other end was fastened to a buoy at the water surface. The pennant line was attached to the flukes of the anchor in such a way that the anchor could be raised in an inverted position. Fifty-gallon, air-tight, gasoline drums painted white, each with an iron band to receive the cable, served as buoys. A swivel was placed in the cable near the buoy in order to keep the line from twisting.

This arrangement served a three-fold purpose: The buoys served to warn vessels to keep clear of the anchor lines. The anchors could be raised in an inverted position and thus prevent snagging or damaging submarine cables. The anchor could be recovered should the main cable break or slip from the drum. These buoys were illuminated by spotlights at night.

(c) *Jetting.*

The drill cage was first lowered from the leads to the bottom. Usually it sank from four feet to eighteen feet into the mud. Three-inch extra heavy pipe with a nozzle which reduced the orifice from 3 inches to $1\frac{1}{2}$ inches was then placed inside the drill cage.

Two pumps connected successively forced water through the jet pipe up to a maximum pressure of 400 pounds. The approximate pressure at nozzle for various depths of boring compared with the gauge pressures are shown by graph on Plate No. 12.

The jetting operation proved very effective in penetrating mud, clay, sand and, in some cases, gravel strata. In one case a gravel stratum 60 feet in thickness was successfully penetrated by this method. However, in some instances the jet pipe was deflected and badly bent after penetrating considerable distance into a gravel stratum.

After the pumps were turned on, the jet pipe would sink by its own weight through mud, soft clay, and sand, but upon reaching stiff clay it would have to be jounced. This was done by raising the pipe several feet and allowing it to fall unrestrictedly.

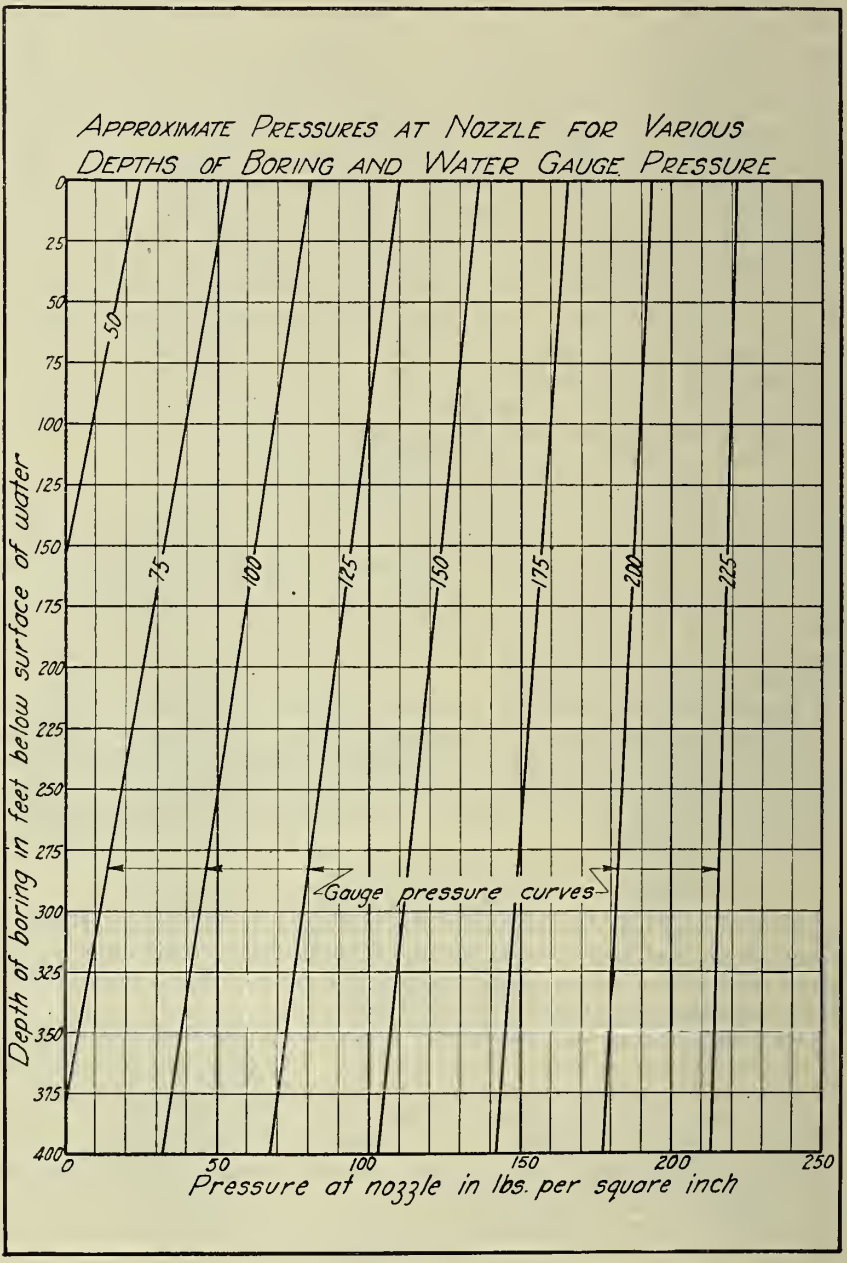

APPROXIMATE PRESSURES AT NOZZLE FOR VARIOUS DEPTHS OF BORING AND WATER GAUGE PRESSURE
Depth of boring in feet below surface of water
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
50
75
100
125
150
175
200
225
Gauge pressure curves
0
50
100
150
200
250
Pressure at nozzle in lbs. per square inch

PLATE No. 12

Two 20-foot sections of pipe were connected and placed on the jet column at one time. As a rule, in order to expedite the work, samples of the material were obtained only at these forty-foot intervals when the pipe had to be disconnected in order to add another section.

(d) *Diamond Drilling.*

Diamond drill cores were taken at certain locations where the jet indicated solid rock to be within a reasonable foundation depth.

The hole was first jetted to the rock by the usual jetting process. The jet pipe was then removed from the hole, the nozzle disconnected and the 3-inch pipe, without the nozzle, was again jetted down the same hole. The 3-inch pipe was then used as a casing for the diamond drill rods.

The drill platform was next hoisted to the top of the drill cage and bolted into position in readiness for the diamond drill machine.

The diamond drill used is shown by photographs included in this report. Its compactness and small weight made it particularly well adapted to the character of the work involved. Two sizes of bits were used equipped with double tube core barrels, yielding cores 2 inches in diameter and $1\frac{1}{8}$ inches in diameter, respectively. The 2-inch core was obtained by placing the drill rods and bit directly inside the 3-inch casing and the $1\frac{1}{8}$-inch by using $2\frac{1}{4}$-inch (outside diameter) casing in combination with the 3-inch casing.

Thoran steel, a very hard steel containing a high percentage of tungsten, was used as settings in place of black carbon most of the time because of its low price in comparison with diamonds. Its cost is less than one per cent of that of diamonds. While the percentage of loss by weight is very much more than diamonds, it was found to be quite satisfactory in most instances, primarily, because of the great risk of losing a bit.

A total of 184.1 feet of rock was drilled with a carbon loss of $267.65, or a loss of $1.45 per foot.

(e) *Difficulties Encountered.*

During the five months that the borings were being taken, from January 30, 1930, to June 26, 1930, only two days were lost because of stormy weather. However, during February and March strong S.E. gales made the bay quite rough, slowed up the progress of the work and, upon several occasions, caused the anchors to drag, but luckily no serious damage was done.

Fogs were quite prevalent during the early part of February. Heavy, low, tule fogs usually hung over the bay until 10:00 a.m. after which the visibility was quite good until about 3:00 p.m. Many times during February, March and April a heavy pall of smoke hung over San Francisco, making it impossible to see points back of the Embarcadero or to distinguish points on the east side of the bay. Usually a light north wind would spring up about 9:30 a.m. and clear the atmosphere.

Many of the borings were within a cable area in which there were thirty-four submarine cables, the exact locations of which were unknown. These cables are owned by the Western Union, Pacific Telephone and Telegraph Company, Postal Telegraph Company and Great Western Power Company; and the breaking or interruption of

service of any one would have resulted in serious loss. Two cables belonging to the Great Western Power Company were located from the surface by means of a special radio. The remaining cables could not be located from the surface, and it was necessary to send a submarine diver to the bottom at each anchor and at the drill cage while boring within the cable area.

The swells from boats were a constant source of hazard, especially while boring in the ferry lanes. Particularly was this true while diamond drilling. Several times our anchor buoys were rammed and sunk, and the anchors dragged several hundred feet. Upon one occasion this caused the drill cage to tip over about 25° from the vertical and bent the casing and drill rods.

The direction and velocity of the tidal current was a big factor in towing the barges from one location to the other. Several times it was necessary to make use of the services of two tugs in order that the work might not be delayed by waiting for a slack water period. Upon one occasion it required the services of four tugs to combat an exceptionally large tidal run-off in combination with strong supporting winds.

(f) *Samples.*

In order to obtain truly representative samples of all materials overlying the rock, drive samples were taken of the materials. These samples were immediately placed in glass fruit jars and sealed.

Samples of materials which the jet pipe penetrated were taken with a one-inch or three-quarter inch pipe coupled to a two and one-half inch perforated pipe with a reducing coupling. The perforations were one-quarter inch drilled holes on about six-inch centers. The object was to allow the water above the sample to escape thus eliminating a hydrostatic head which would push out the sample as the pipe was raised above the surface of the water. The 2½-inch pipe was 12 feet long and weighted with lead. The small, or sample pipe, was 18 inches long. For sampling hard materials, a three-quarter inch pipe was used with a one-half inch drill bit riveted inside the sample pipe. In obtaining samples of the softer materials, a one-inch sample pipe with a brass valve at the lower end of the pipe was used. Sketches of these sampling devices are shown on Plate No. 13.

In taking samples this apparatus was lowered through the jet pipe to the bottom by means of a ⅝-inch cable attached to drum on hoisting engine, raised a few feet and dropped. Upon withdrawal of the tool the sample was easily and quickly extracted. Each sample, after being placed in a glass fruit jar and properly labeled, was shipped to the State Department of Public Works, Division of Highways, Bridge Department, at Sacramento.

Representative samples of bedrock were obtained in the usual way by drilling into the rock with a diamond drill. All cores obtained were also retained in glass fruit jars.

Wash samples, in the form of sludge, were obtained by catching the return water from diamond drilling operations at the top of the casing. Sludge samples were saved only where the material did not core, as wash samples are not representative of the material penetrated; inasmuch as only the fines are carried up in suspension due to the fact that the velocity of the water returning up the casing is not sufficient to carry the heavier material.

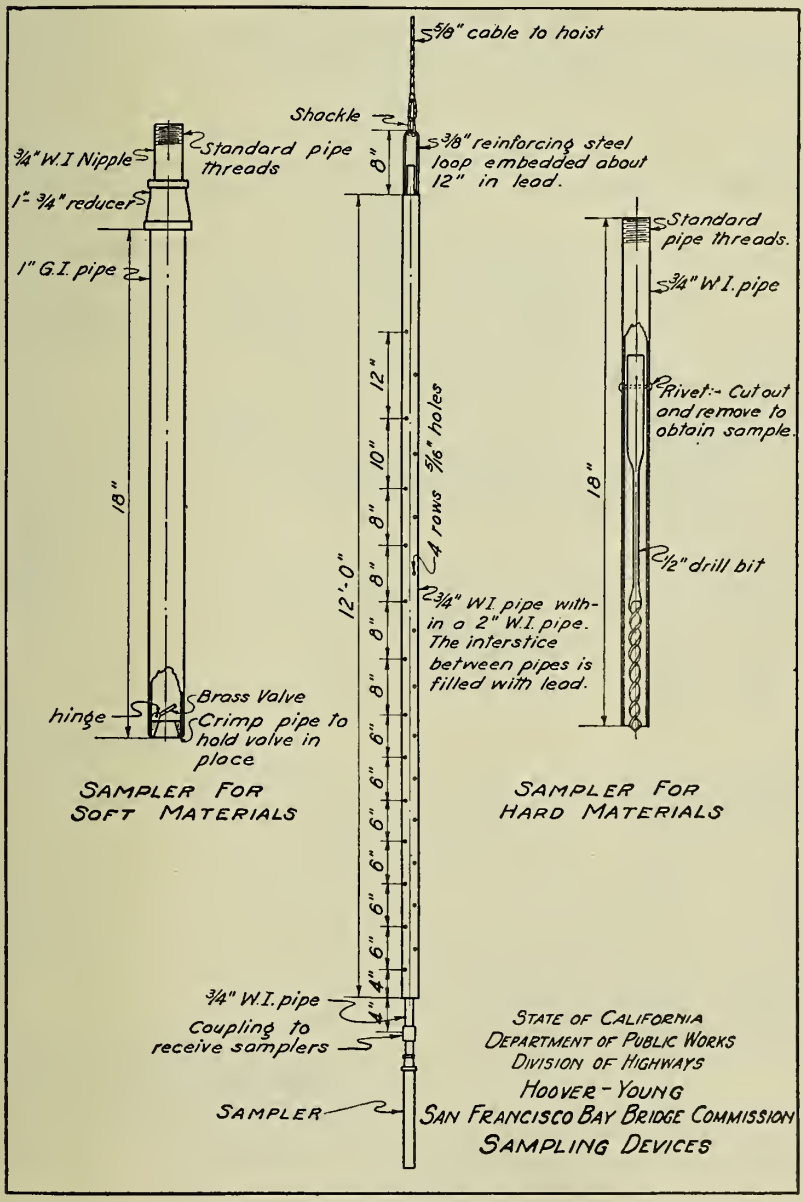

5/8" cable to hoist
Shackle
3/8" reinforcing steel loop embedded about 12" in lead.
3/4" W.I Nipple
Standard pipe threads
8"
1"-3/4" reducer
1" G.I. pipe
18"
12'-0"
12"
10"
8"
8"
8"
8"
6"
6"
6"
6"
6"
6"
4"
4 rows 5/8" holes
2 3/4" W.I pipe within a 2" W.I. pipe. The interstice between pipes is filled with lead.
hinge
Brass Valve
Crimp pipe to hold valve in place
SAMPLER FOR SOFT MATERIALS
Standard pipe threads.
3/4" W.I. pipe
Rivet:- Cut out and remove to obtain sample.
18"
1/2" drill bit
SAMPLER FOR HARD MATERIALS
3/4" W.I. pipe
Coupling to receive samplers
SAMPLER
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER - YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
SAMPLING DEVICES

PLATE No. 13

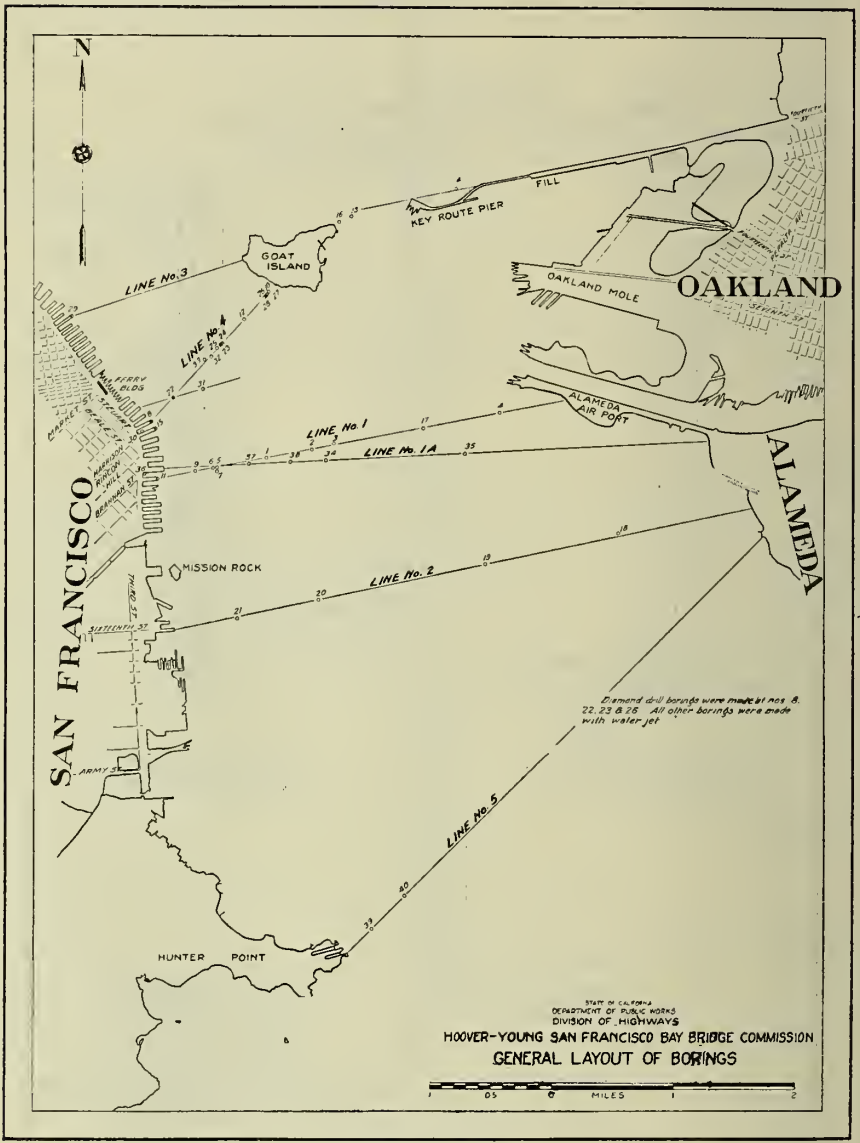

N
FILL
KEY ROUTE PIER
GOAT ISLAND
LINE No. 3
LINE No. 4
OAKLAND MOLE
OAKLAND
FERRY BLDG
LINE No. 1
LINE No. 1A
ALAMEDA AIR PORT
ALAMEDA
SAN FRANCISCO
MISSION ROCK
LINE No. 2
SIXTEENTH ST
Diamond drill borings were made at nos. 8, 22, 23 & 26. All other borings were made with water jet
ARMY ST
LINE No. 5
HUNTER POINT
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
GENERAL LAYOUT OF BORINGS
MILES

PLATE No. 14

7. Lines upon which foundation investigations were made.

Borings were taken on five different lines. Three of these lines are approximately those designated in the 1927 report.

For the sake of retaining their identity and of cross reference to the 1927 report, the same numbers will be given to them herein. References in this report to the various lines will be made by the following identifying numbers, which are shown graphically on Plate No. 14.

Location No. 1. A line drawn from Pier 34 on the San Francisco side to a point approximately 900 feet south of the Alameda Mole on the Oakland side. This line is approximately identical with Location No. 1 in the 1927 report.

Location No. 1-A. A line drawn from Pier 32 on the San Francisco side and passing through a point approximately 2300 feet south of the end of Alameda Mole to the Alameda shore.

Location No. 2. A line drawn from the foot of 16th street in an easterly direction to the Alameda Mole, following approximately the line designated as Location No. 2 in the 1927 report.

Location No. 3. A line drawn from the end of Pier 21 on the San Francisco side to the northwesterly portion of Goat Island, thence across Goat Island and the east bay to the Key Route Mole. This location is approximately identical with the line designated as Location No. 3 in the 1927 report.

Location No. 4. A line drawn from Pier 22 on the San Francisco shore and passing practically over the center of Goat Island; thence over the east bay to the Key Route Mole.

Location No. 5. A line drawn from Hunter Point on the west bay shore in a northeasterly direction toward Alameda.

8. Results of boring operations.

The results of borings are plotted on profiles of each line. The log of each boring is plotted, showing the various materials encountered and a contour map, Plate 19, is developed from these results, showing an approximate topography of hard material levels.

In general, surface muck is first encountered which varies from a black, slimy muck to a soft, plastic clay. As depth is gained, the clay becomes sandy, compact and hard, until just before reaching the hard rock formation, it has the appearance of soft sandy shale, or sandstone. In the east bay area near the Key Route Pier and Alameda Mole, sand and gravel strata of various thicknesses were found interlaid with impervious clay. Gravel was not encountered on the Goat Island lines from San Francisco to the west side of Goat Island.

The rock in all cases is Franciscan sandstone and shale, sometimes alternating in layers from two feet to ten feet thick. The sandstone varies from poorly cemented, coarse grained material, to extremely hard, silicious material. In most instances the rock was broken up by characteristic slaty cleavages. In some instances, due to the many seams and the steep inclination of the cleavages, some of the rock was ground up in the core barrel. An exception to the general rule was found near the west side of Goat Island, where a concealed lens of chert was core drilled. It was found imbedded in a shale stratum which is not unusual in a Franciscan formation.

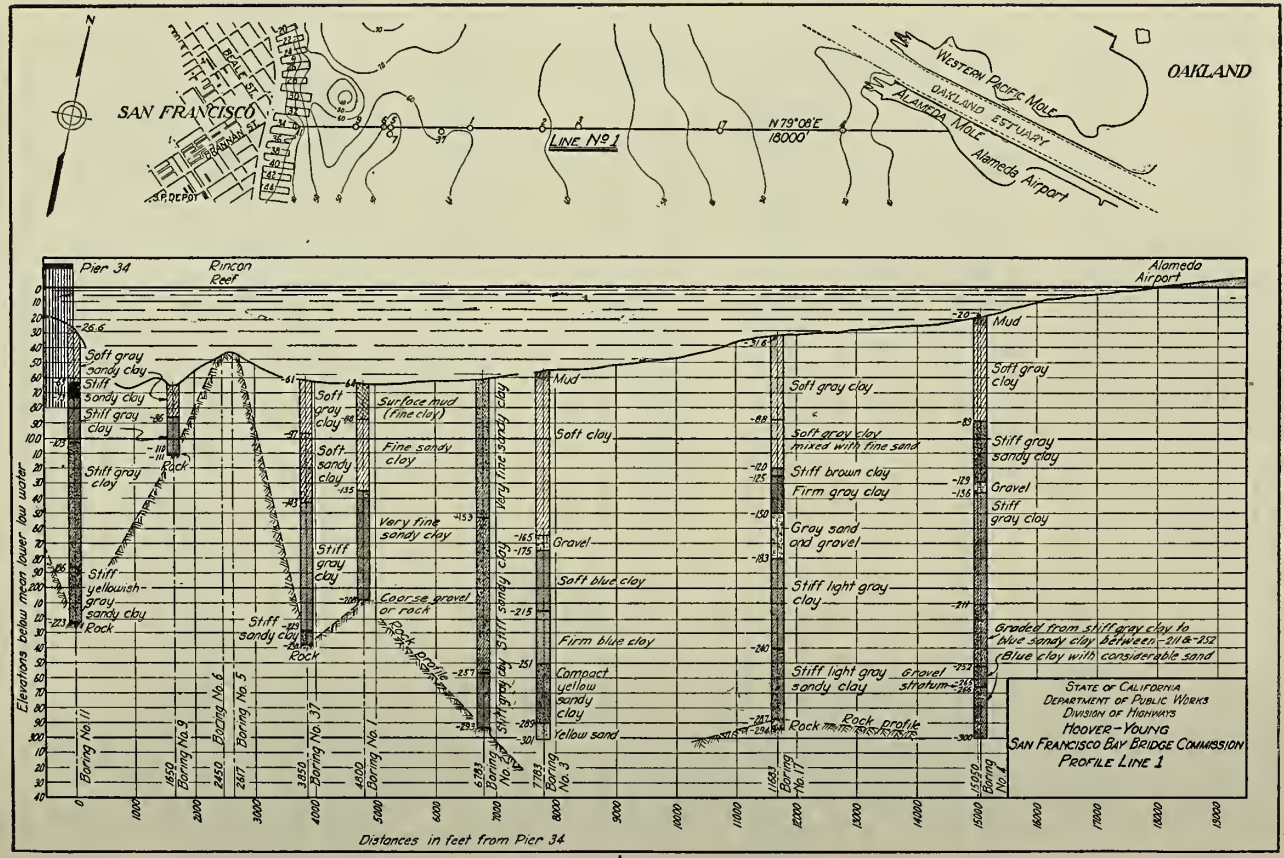

N
SAN FRANCISCO
BEALE ST.
BRYANT ST.
S.P. DEPOT
LINE No 1
N 79°08'E
18000'
WESTERN PACIFIC MOLE
OAKLAND ESTUARY
ALAMEDA MOLE
Alameda Airport
OAKLAND
Pier 34
Rincon Reef
Alameda Airport
Elevations below mean lower low water
Distances in feet from Pier 34
Soft gray sandy clay
Stiff sandy clay
Stiff gray clay
Rock
Stiff yellowish-gray sandy clay
Soft gray clay
Surface mud (fine clay)
Fine sandy clay
Soft sandy clay
Very fine sandy clay
Stiff gray clay
Coarse gravel or rock
Rock profile
Mud
Soft clay
Gravel
Soft blue clay
Firm blue clay
Compact yellow sandy clay
Yellow sand
Soft gray clay
Soft gray clay mixed with fine sand
Stiff brown clay
Firm gray clay
Gray sand and gravel
Stiff light gray clay
Stiff light gray sandy clay
Gravel stratum
Graded from stiff gray clay to blue sandy clay between -211 & -252 (Blue clay with considerable sand
Stiff gray sandy clay
Gravel
Stiff gray clay
Boring No 11
Boring No 9
Boring No 6
Boring No 5
Boring No 37
Boring No 1
Boring No 4
Boring No 3
Boring No 17
Boring No 7
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
PROFILE LINE 1

PLATE No. 15

9. Discussion of boring results.

(a) *Location No. 1.*

The holes taken on Location No. 1 are: Nos. 36, 11, 9, 6, 5, 7, 1, 2, 3, 17 and 4.

Boring No. 36 is located 16.3 feet east of the bulkhead along the east side of the Embarcadero and 9 feet off the south side of Pier 32. It is in the immediate vicinity of a proposed anchor pier. The jet penetrated to elevation –162.8, where it encountered hard material, probably shale. At elevation –76 a stratum of sand and clay was encountered. Above –76, the material was very soft and of a character which would afford practically no bearing power.

Material below –76 is of such a character that it would afford a good bearing for piles.

Indications are that a pier with its base at –50 and supported on piles driven to –110 would give a satisfactory foundation. Battered piles would be required around the outer edge to afford resistance to lateral forces.

Boring No. 11. Boring No. 11 is located at the end of Pier 34. The depth of water is 27 feet.

It would be necessary to construct the first main supporting pier at this point. This pier would support the cantilever arm of the first long span and would be subjected to a total direct load from the superstructure of approximately 55 million pounds in addition to the weight of the pier. Any appreciable settlement in such a pier would be fatal to the structure. It is, therefore, very necessary that foundation pressures be conservative.

Study of the material encountered indicates that no material which would offer suitable resistance to piles is present above –186. It is almost certain that they would have to be driven to –200. The ability for a pile foundation to resist the enormous lateral forces due to earth shocks is very doubtful, even with a large percentage of battered piles. The base of a pier founded on piles would have to be very large because of the fact that the bottom of the base block would be required to be placed at least to –70. Assuming piles to –200 would require the use of 135-foot piles driven with an under-water hammer. Such construction is not believed to be practical.

The remaining alternative is to omit piles and sink the pier to shale or rock at a depth of 230 feet. Such a depth of foundation, while unprecedented, is believed to be entirely feasible and is found to result in foundation pressures which are permissible on shale or rock.

Boring No. 9. Boring No. 9 is located on Line No. 1 approximately 1650 feet from Pier 34. The water is 65 feet deep at this point.

The material overlying rock is soft clay. Rock was encountered at Elevation –110.0. It would be necessary to place a main tower pier supporting two cantilever arms for 1700-foot spans approximately 400 feet east of this boring and in closer proximity to borings 5, 6 and 7.

Borings Nos. 5, 6 and 7. These holes are on the site of Rincon Rock. This rock formerly was of such a height as to be a menace to navigation and was removed by the U. S. Engineers to a depth of approximately 40 feet below water.

Boring No. 5 is located approximately 2617 feet from the end of Pier 34 and 2200 feet from the pier head line. Boring No. 6 is on the same line and 2050 feet east of the pier head line. Boring No. 7 is offset to the south from No. 5.

Each of these three holes shows hard rock or shale at approximately elevation –48. There is evidently a layer of loose rock approximately 5 feet deep overlying hard material, probably debris from blasting.

This rock affords an excellent foundation for the heavy pier. Steel sheet piling can be used for open caisson work. It is believed that steel piling can be driven a sufficient distance into the hard material to be satisfactory for open caisson work.

Boring No. 1. Boring No. 1 is located 4800 feet east of Pier 34 on Location No. 1 and is in 64 feet of water. The jet penetrated to –208 at this hole. At this depth the jet pipe was deflected sidewise and broken. The material was very hard at –208 but it was difficult to obtain a good sample of the material. The drill crew was new at the work and the best methods of sampling had not yet been determined. Due to this fact the conditions in this vicinity were later checked by Boring No. 37, which will be discussed later.

Boring No. 2. Boring No. 2 is located 6783 feet from Pier 34 in 61 feet of water. The jet penetrated to –293 feet. Material was medium soft down to –153 where a stiffer material was encountered. At –170 a very dense stratum was penetrated to –194. It is probable that piles would bring up hard between –160 and –170. A pier without piles would probably reach safe bearing for moderate spans at –170.

Boring No. 3. Boring No. 3 is located 7783 feet from Pier 34 in 56 feet of water. The foundation is very similar to that found at Boring No. 2 and approximately the same depths of piers would be required as at No. 2.

Boring No. 4. Boring No. 4 is located 15,050 feet from Pier 34 in 20 feet of water. Material was soft to –89. From elevation –89 to –129 the material is stiff clay with some fine sand. At –129 a stratum of gravel about 7 or 8 feet thick is underlaid with a soft clay stratum. Piles would drive hard at –129 to –136 but should penetrate through the soft layer below and into the blue clay at –170.

A pier founded at –130 without piles would be of doubtful value because of the comparatively soft strata below –140. This is especially true for 750-foot spans.

Boring No. 17. Boring No. 17 is located 11,683 feet from Pier 34 in 31.6 feet of water. The overlying stratum at this point is quite soft above –150, with no great lateral stability. At –150 a layer of gravel 25 to 30 feet thick was encountered.

A pier without piles would obtain adequate bearing at approximately –155 or –160. Due to the lack of lateral stability at Boring No. 17 in the upper strata, a pile foundation would be of doubtful character.

All foundations depending on piles on this line would require a large number of battered piles to take the lateral thrust. It is of course necessary to place the bottom of concrete well below the bottom surface —at least 20 feet. In 60 feet of water this would mean that the concrete base, below which the piles extend, would be 80 feet below water. It is virtually impossible to drive battered piles in such a depth of water with either a follower or under-water hammer. Consequently the con-

struction of a heavy pier in deep water, resting on piles, is very difficult.

The difficulty of driving battered piles coupled with the fact that the lateral stability of battered piles is doubtful leads to the conclusion that it would be necessary to sink piers without piles to the underlying stratum capable of taking the required bearing.

(b) *Location No. 1-A.*

Borings Nos. 34, 35, 37, and 38 are located on Location No. 1-A. This line starts, on the San Francisco side, at Pier 32 and bears somewhat southward from Location No. 1, passing over Rincon Rock and intersecting the Alameda shore to the south of Location No. 1. Location No. 1-A makes a satisfactory crossing under the estuary without excessive curvature.

Boring No. 37. Boring No. 37 is located 3700 feet from Pier 32 in 61 feet of water. Material penetrated between –61 and –97 is a very soft clay with no lateral stability. Material between –97 and –143 is slightly stiffer clay with some sand. This material would afford some side stability and probably a considerable amount of surface friction to piles. Material between –143 and –229 is a stiff gray clay and piles driven into this material 25 or 30 feet would probably afford a maximum pile bearing. The question of side stability to resist the horizontal forces of earth shocks is very questionable when piles are driven for 70 or 75 feet through soft material before entering the more rigid strata below.

A cellular pier sunk to –150 or –155 in the vicinity of Boring No. 37 would be far superior and would probably be safe against direct foundation pressures of 5 tons per square foot.

Boring No. 38. Boring No. 38 is located 5483 feet from Pier 32 in 62 feet of water. Material is very soft to elevation –136. At –136 a thin stratum of cemented sand is found to overlie a layer of sand and gravel between –140 and –175. The successive layers of material from –175 to rock at –254 are very firm. It is believed that a pier without piles sunk to elevation –140 will afford a suitable foundation, the direct load being limited to approximately 5 tons per square foot.

Boring No. 34. Boring No. 34 is located 7033 feet from Pier 32 in 58 feet of water. The jet penetrated to elevation –307. Material penetrated to elevation –160 is a very soft clay with some very fine sand. At elevation –160 a very compact stiff gray clay stratum 62 feet thick was encountered. This clay overlies sand. A cellular pier sunk to elevation –165 or –170 at this location is considered safe.

Boring No. 35. Boring No. 35 is located 12,950 feet from the end of Pier 32 and in 27 feet of water. The jet penetrated to elevation –300.5. Material to elevation –132 is very soft with no lateral stability. Between elevation –132 and –155 a stiff gray clay was penetrated. This is a stratum which would afford satisfactory lateral stability to piling. An artesian flow of water was brought in just below this stratum indicating that it is a more or less continuous impervious stratum under which there is a stratum containing a large amount of sand and gravel.

Piles driven to elevation –160 would probably afford a suitable foundation. Battered piles would be required to resist lateral thrust. A pier without piles sunk to –155 or –160 would afford good bearing and is desirable.

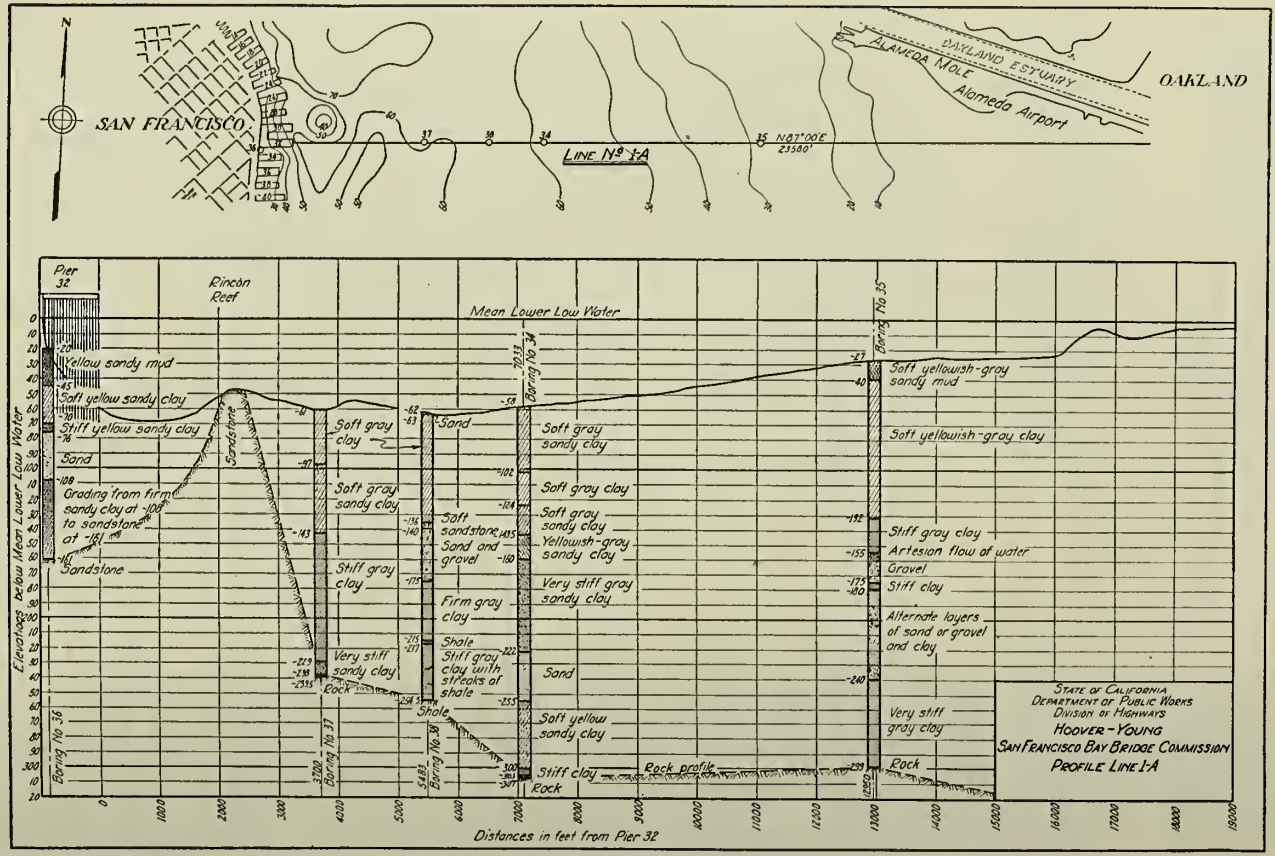

N
SAN FRANCISCO
OAKLAND ESTUARY
ALAMEDA MOLE
Alameda Airport
OAKLAND
LINE No. 1-A
N87°00E
23580'
Elevations below Mean Lower Low Water
Pier 32
Rincon Reef
Mean Lower Low Water
Yellow sandy mud
Soft yellow sandy clay
Stiff yellow sandy clay
Sand
Grading from firm sandy clay at -108 to sandstone at -161
Sandstone
Soft gray clay
Soft gray sandy clay
Stiff gray clay
Very stiff sandy clay
Rock
Shale
Sandstone
Soft gray sandy clay
Soft sandstone
Sand and gravel
Firm gray clay
Shale
Stiff gray clay with streaks of shale
Rock
Sand
Soft gray clay
Soft gray sandy clay
Soft gray clay
Soft gray sandy clay
Yellowish-gray sandy clay
Very stiff gray sandy clay
Soft yellow sandy clay
Stiff clay
Rock
Rock profile
Boring No. 36
Boring No. 37
Boring No. 38
Boring No. 34
Boring No. 35
Soft yellowish-gray sandy mud
Soft yellowish-gray clay
Stiff gray clay
Artesian flow of water
Gravel
Stiff clay
Alternate layers of sand or gravel and clay
Very stiff gray clay
Rock
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER - YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
PROFILE LINE 1-A
Distances in feet from Pier 32

PLATE No. 16

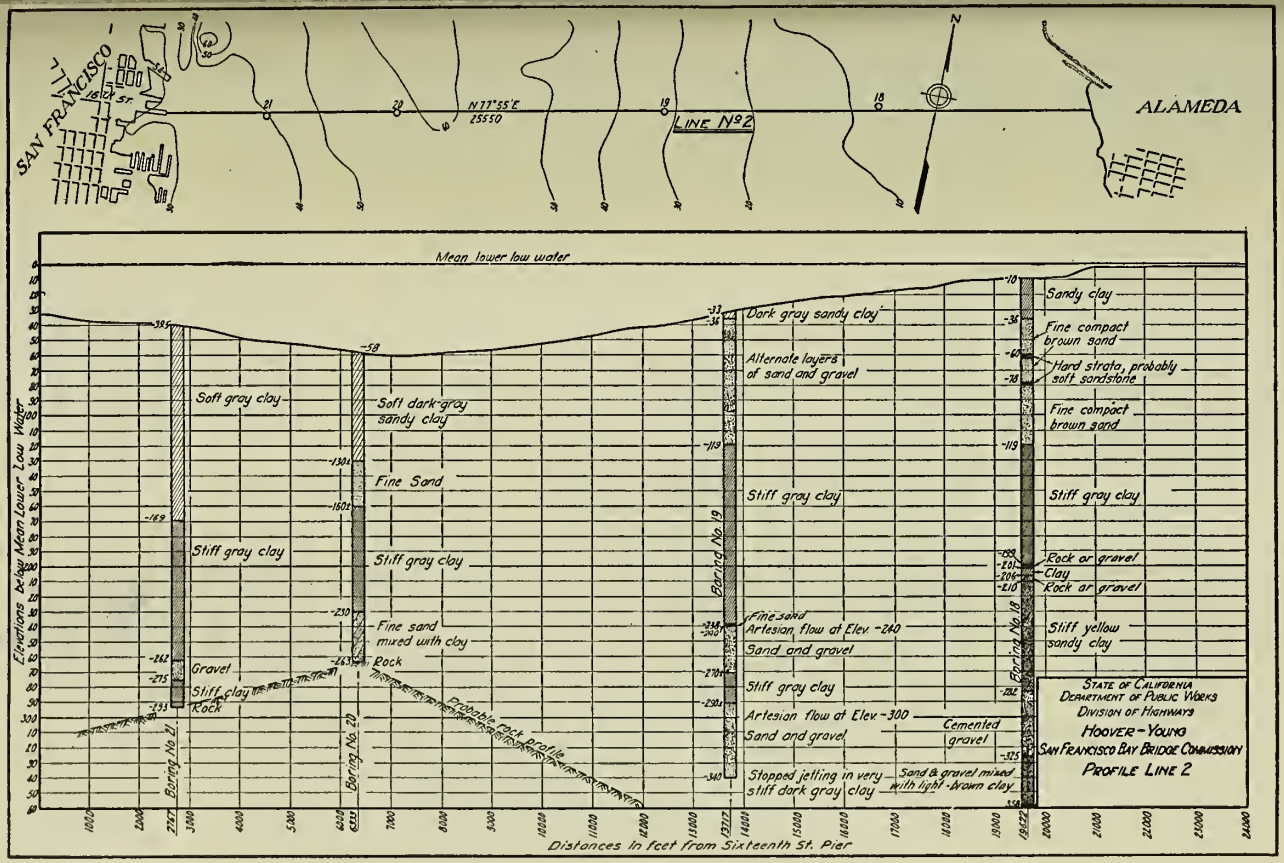

SAN FRANCISCO
ALAMEDA
N 77°55'E
25550
LINE No 2
Mean lower low water
Elevations below Mean Lower Low Water
Soft gray clay
Stiff gray clay
Gravel
Stiff clay
Rock
Boring No. 21
Soft dark gray sandy clay
Fine Sand
Stiff gray clay
Fine sand mixed with clay
Rock
Boring No. 20
Probable rock profile
Dark gray sandy clay
Alternate layers of sand and gravel
Stiff gray clay
Fine sand
Artesian flow at Elev -240
Sand and gravel
Stiff gray clay
Artesian flow at Elev -300
Sand and gravel
Stopped jetting in very stiff dark gray clay
Boring No. 19
Sand & gravel mixed with light brown clay
Cemented gravel
Sandy clay
Fine compact brown sand
Hard strata, probably soft sandstone
Fine compact brown sand
Stiff gray clay
Rock or gravel
Clay
Rock or gravel
Stiff yellow sandy clay
Boring No. 18
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER - YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
PROFILE LINE 2
Distances in feet from Sixteenth St. Pier

PLATE No. 17

(c) *Location No. 2.* Borings Nos. 18, 19, 20 and 21 are located on Line No. 2.

Boring No. 18. Boring No. 18 is located 19,622 feet from the 16th Street Pier in 10 feet of water. The jet penetrated to –359 feet at which point the nozzle was in gravel. Material to –39 was found to be sandy clay. Between elevation –39 and –59 the strata penetrated were very firm and composed of stiff sandy clay and fine sand. These strata would no doubt afford a suitable pile foundation for reasonably heavy bridge piers. The fact that artesian flow was encountered at different elevations indicates stiff impervious layers alternating with sand and gravel layers.

Boring No. 19. Boring No. 19 is located 12,000 feet from the Alameda shore and 13,717 feet from the 16th Street Pier in 33 feet of water. The jet penetrated to –340 feet. Samples taken at elevations –33, –119 and –149 indicate a stiff clay with a considerable amount of sand. Artesian flow was encountered at elevation –198. It is probable that piling would drive hard and attain bearing at elevation –120 to –140. Sample No. 2 is a stiff sandy clay and would afford considerable lateral stability. By using battered piles a satisfactory foundation could probably be obtained for spans up to 400 or 450 feet. It is, of course, impracticable to sink piers to the depth of either Boring No. 18 or 19.

Boring No. 20. Boring No. 20 is located 6300 feet from 16th Street Pier in 57.7 feet of water. Material down to elevation –149 is a soft clay mixed with a small amount of sand.

At elevation –149 a stratum of fine sand was encountered. This layer of sand is of such a character as to afford a pile bearing for reasonably heavy piers. The stratum above –149, however, does not indicate satisfactory side stability against lateral forces and batter piles would be necessary.

Boring No. 21. Boring No. 21 is located 2767 feet from the 16th Street Pier in 39.5 feet of water. The material down to elevation –175 is so soft that the jet pipe sank under its own weight. No sandy material was present in any of the strata below –175 and above –293. At –293 a hard stratum, apparently rock, was encountered. This boring is in the immediate vicinity of heavy piers necessary to support a long span.

It is very doubtful whether any safe bearing for such a pier could be obtained above elevation –293. It is not considered practicable to go to such a depth. For this reason the possibility of building a bridge on this location is doubtful and the line has been abandoned.

(d) *Location No. 3.*

Boring No. 29 and two core drill borings formerly made by the Inter Cities Bridge Company are on this line.

Boring No. 29. Boring No. 29 is located just off the end of Pier 21 in 39 feet of water. Rock was encountered at elevation –211. A structure on this line requires long spans, which result in very heavy pier reactions. It is not considered safe to stop such pier foundations before reaching rock or shale. It is, therefore, necessary to sink piers in the vicinity of Boring No. 29 to approximately elevation –220. Such a depth is considered feasible but is, of course, very expensive.

Records of two additional borings have been made available to the department for this report—one located midway between Pier 21 and Goat Island and the other approximately 2000 feet west of Goat Island.

The hole midway between Pier 21 and Goat Island disclosed sandstone and shale at elevation –208 overlain with clay, sand and shells. The second hole disclosed sandstone and shale at elevation –254 feet, overlain with clay, sand and shells. Piers on this line will be very heavy and subject to high lateral forces. For this reason it is considered necessary to sink all piers to the sandstone and shale strata.

(e) *Location No. 4.*

Borings Nos. 30, 8, 22, 33, 32, 25, 23, 24, 12, 28, 26, 27, 10, 16, 13 and 14 are on this line.

Boring No. 30. Boring No. 30 is close to the Embarcadero bulkhead just off the north side of Pier 24. It is practically on the site of a proposed anchor pier. Shale or rock was encountered at a depth of –120. An excellent foundation can be developed either on piles driven to the shale or by sinking a pier to shale.

Boring No. 8. Boring No. 8 is located at the end of Pier 22 on the center line of pier. Hard shale was encountered at elevation –163.5. This hole was core drilled. Shale of varying degrees of hardness was encountered from elevation –163.5 to –207 where core drilling was discontinued. This hole is at the outside edge of the first heavy bridge pier. Due to the heavy reactions and major lateral forces acting it will be necessary to sink this pier to shale. It is considered that an excellent foundation can be obtained at elevation –180 and designs are estimated on that basis.

Boring No. 22. Boring No. 22 is located 1417 feet from the end of Pier 22 in 76 feet of water. This hole was first jetted to rock and then core drilled. The jet penetrated through clay to elevation –190, then through stiff clay and sand to –216 where jet refusal was reached. The core drill was then set up. From elevation –216.5 to –226 the core drill disclosed hard shale and from elevation –226 to –232.8 hard sandy shale. From –232.8 to –265.9 the drill passed through alternate layers of shale and sandstone which increased in hardness as the drill advanced.

An excellent foundation for the heavy pier near this hole can be obtained at elevation –225 or –230 and designs are estimated on this basis, assuming that pier bases are set into the shale an average of 15 feet.

Boring No. 33. Boring No. 33 is located 3533 feet from Pier 22 in 68 feet of water. The jet penetrated stiff gray clay from elevation –111 to –186. At elevation –186 the jet came to refusal on rock.

Boring No. 32. Boring No. 32 is located 3833 feet from Pier 22 in 64 feet of water. The jet penetrated clay to elevation –155.4 where shale was encountered. Pier 4 is located between Borings Nos 33 and 34, and consists of four main pedestals. It is considered that an excellent foundation can be obtained at an average elevation of –180 to –185.

Borings Nos. 23, 24 and 25. Boring No. 23 is located a distance of 4450 feet from Pier 22 in 66.5 feet of water. The jet penetrated

gray sandy clay to elevation –135 where a hard stratum was encountered. The jet penetrated the layer to –137 where shale was encountered.

The diamond drill was then set up and drilling continued to elevation –169.6. The diamond drill penetrated shale, from –146 to –169.6, all of which was streaked with veinlets of calcite.

Borings Nos. 24 and 25 were 150 feet east and 200 feet west, respectively, of Boring No. 23. These borings were taken to check the elevation of the rock as found at Boring No. 23 and to determine its slope.

In Boring No. 24 shale was encountered at elevation –131 and in Boring No. 25 shale was encountered at –146, indicating a slope downward to the west and north. The material encountered below elevation –138 is indicative of the character of shale which may be expected. There is no doubt but that the material has sufficient bearing power to support the necessary loads safely.

Boring No. 12. Boring No. 12 is located 5967 feet from Pier 22 in 92 feet of water. The jet penetrated through stiff clay mixed with fine sand from –144 to –158.5 where shale and rock fragments were encountered. The jet could not penetrate below –158.5.

This boring is about 200 feet east of Pier 5.

The rock line plotted between Boring No. 12 and Boring No. 24 indicates a slope upward to the west. It is considered that an excellent foundation for Pier No. 5 can be obtained at elevation –160 or –165.

Borings Nos. 10, 26, 27 and 28. These borings represent a group of holes centered around Boring No. 26.

Boring No. 26 is 7333 feet from Pier 22 and approximately 600 feet from the shore of Goat Island.

Boring No. 10 was put down first in 51 feet of water. The jet penetrated fairly easily to –82 where the material gradually became harder until jet refusal was reached at elevation –87.2.

Boring No. 26 was put down later to check the hard material. Considerable difficulty was encountered at this hole. The jet penetrated through surface muck to –114, then through stiff blue clay to elevation –133.3 where a stratum of shale was encountered. At elevation –134.5 a lens of chert was encountered which extended to –139.4. This chert could not be cut with the Thoran steel bit and over one carat of diamonds was lost due to breakage and wear in drilling the 5 feet. Underlying the chert was a 5-foot layer of soft shale. From –144.5 to –150 a hard grained sandstone was encountered which was interlain with layers of soft material. From –150 to –166 there is a layer of fine green sand and from –166 to –180 a layer of serpentine. Hard and soft layers of shale extend from –180 to –188.6. From elevation –188.6 to –194.7, the bottom of the boring, the diamond drill cored hard serpentine with a few thin layers of soft material.

The presence of the lens of hard rock between –134.5 and –139.4 is characteristic of the sandstone and shale formations in the bay area. There is no rock of similar character to be found on Goat Island. Its geological classification is chert and in the opinion of geologists the lens is quite small in extent. This fact is borne out by Boring No. 28 which was sunk 90 feet west of Boring No. 26 and did not encounter such material.

It is considered necessary to sink Pier 6, which is located about

100 feet west toward Goat Island from Boring No. 26, to an elevation of –180 in order to get below the depression in this stratum of shale as shown by Borings No. 28 and No. 27. At Boring No. 27 shale was encountered at a depth of –126 and at Boring No. 28 it was encountered at –160. These borings indicate the shale slope on the west side of Goat Island.

Borings Nos 13, 14 and 16. These borings are east of Goat Island and may be considered as being on either Location No. 3 or 4.

Boring No. 13. Boring No. 13 is located approximately 830 feet from the east shore of Goat Island and between the end of the Key Route Mole and the Goat Island shore. The depth of water is 51 feet. The jet went down easily to elevation –98. At elevation –108 the jet was in stiff blue clay. At elevation –148 stiff gray clay mixed with shells was encountered. Alternate lavers of clay were penetrated to –230 where a very stiff clay mixed with gravel was encountered.

Jet refusal was reached at –269.5.

Boring No. 16. Boring No. 16 is located approximately 270 feet off Goat Island and 8480 feet from the end of the Key Route fill. Rock was encountered at elevation –217. Material down to elevation –169 was a stiff clay which required 250 pounds pressure per square inch to penetrate. At –169 a layer of sand, clay and shells was encountered which extended to –210. At elevation –217 the jet came to refusal.

Pier 9, the first pier for the cantilever arm east of Goat Island, is approximately 240 feet west of Boring No. 16 and about 100 feet off Goat Island. Rock at Boring No. 16 was at elevation –217. At the Goat Island shore the rock is at elevation 0.00. Assuming a uniform slope between these points indicates rock elevation at the center line of Pier 9 at approximately –75. This pier has been designed to rest on concrete piles driven to shale.

Pier 10 supporting the east cantilever arm is located approximately 520 feet east of Boring No. 16 and 100 feet west of Boring No. 13. The rock slope defined by a line between Borings Nos. 13 and 16 indicates that this pier should be sunk to –250. A cellular pier is designed for this purpose.

Pier 11 is approximately 160 feet east of Boring No. 10. This pier is subject to comparatively light loads due to the uplift factor from the superstructure. It is considered satisfactory to support this pier on concrete piles driven through stiff blue clay to a layer of stiff gray clay at elevation –148.

Boring No. 14. Boring No. 14 is located approximately 2000 feet east of the end of the Key Route Pier in 10 feet of water. Material penetrated by the jet down to –130 was a gray clay and sand. Piers 12 and 32, inclusive, are supports for 300-foot spans. The reactions are such that it is considered safe to use pile foundations driven through the sandy clay to –135 or 140 feet.

(f) *Location No. 5.* Borings Nos. 39 and 40.

Boring No. 39. This boring is located N. 45° 00′ E., 1683 feet from Hunter Point Drydock in 69 feet of water. Material down to –125 is very soft with no lateral stability. From –125 to –137 there is a stratum of firm yellowish gray sandy clay, and from –137 to –236 very stiff gray clay. The material from –135 to –137 would afford good side

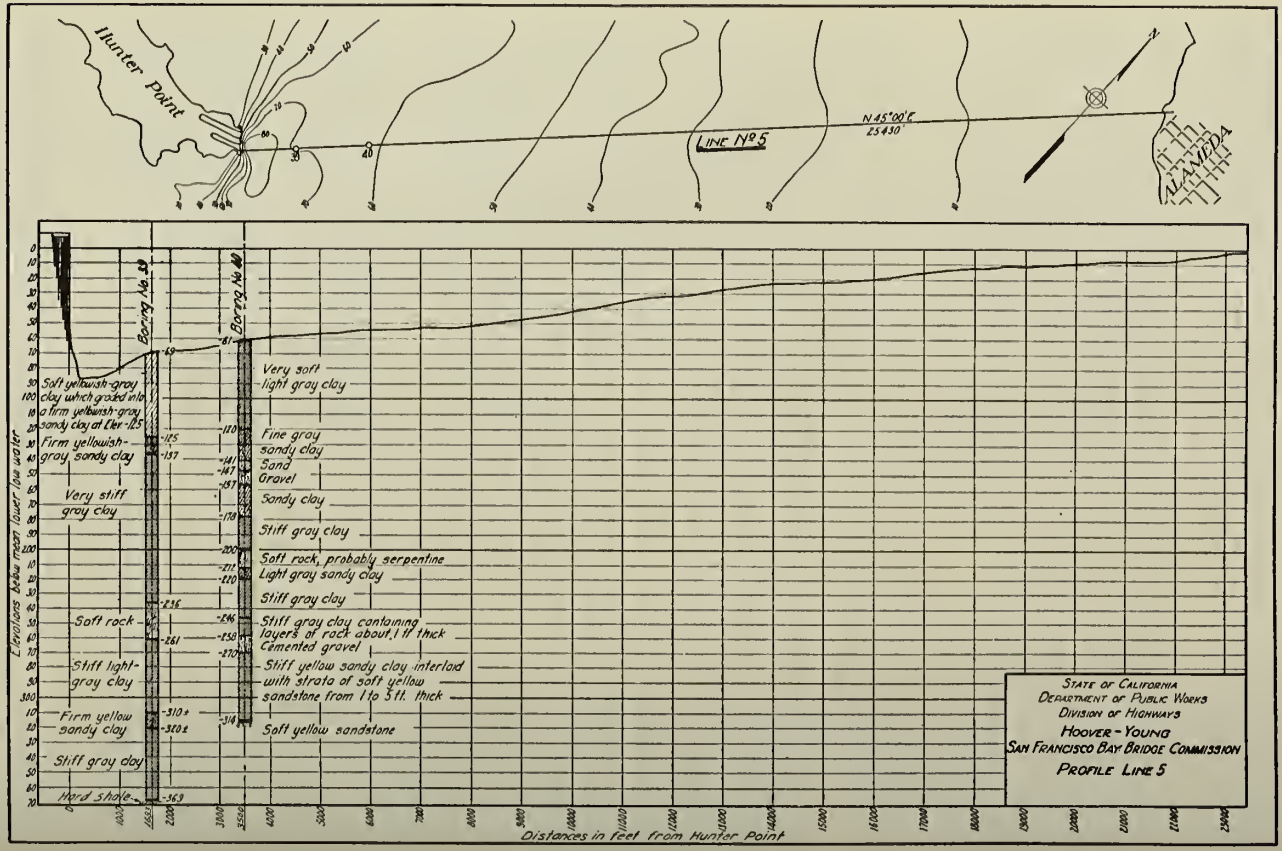

Hunter Point
LINE No 5
N 45°00' E
25430'
ALAMEDA
Boring No 9
Boring No 10
Elevations below mean lower low water
Soft yellowish-gray clay which graded into a firm yellowish-gray sandy clay at Elev -125
Firm yellowish-gray sandy clay
Very stiff gray clay
Soft rock
Stiff light-gray clay
Firm yellow sandy clay
Stiff gray clay
Hard Shale
Very soft light gray clay
Fine gray sandy clay
Sand
Gravel
Sandy clay
Stiff gray clay
Soft rock, probably serpentine
Light gray sandy clay
Stiff gray clay
Stiff gray clay containing layers of rock about 1 ft thick
Cemented gravel
Stiff yellow sandy clay interlaid with strata of soft yellow sandstone from 1 to 3 ft. thick
Soft yellow sandstone
Distances in feet from Hunter Point
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER - YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
PROFILE LINE 5

PLATE No. 18

stability and considerable pile bearing for reasonably long spans. However, the material is not as satisfactory as that at Boring No. 40.

Boring No. 40. Boring No. 40 is located N. 45° 00′ E., 3500 feet from Hunter Point Drydock in 61 feet of water. Soft clay was penetrated to elevation –120, from elevation –120 to –141, sand, and from –141 to –157, gravel. These combined strata give promise of a satisfactory bearing power for pile foundations under moderately long spans. This is particularly true due to a firm stratum below elevation –157.

These two borings are in the immediate vicinity of piers which would be required to sustain a long channel span probably 1000 or 1200 feet. With proper provisions for battered piles to develop side stability and large pier bases to distribute the pile loads, it is believed that a proper foundation can be constructed to support such a span. Piers can not be sunk to shale near Boring No. 39 or No. 40 on account of the great depth to such material.

Boring No. 41. Boring No. 41 is taken alongside the first pier west of the west end of the lift span of the San Mateo-Hayward Bridge. This boring was taken for the sole purpose of determining the action of the jet in, and to obtain samples of, material on the bay bottom which is known to have developed satisfactory pile bearing. The jet boring indicates a soft sandy material from the surface. From –45 to –72 a clay was penetrated which contains a small amount of sand. From –72 to –84 a light gray sandy clay was penetrated. This light gray sandy clay is similar in appearance to that found in many of the other borings, but is found much nearer the surface. Immediately under this layer of clay a 12-foot layer of compact gravel was encountered and it is on this layer of gravel that the piles of the San Mateo-Hayward Bridge found bearing.

The record of piles driven in a pier of the San Mateo-Hayward Bridge within 100 or 150 feet of this boring indicates that piles sank under their own weight through the upper clay strata, bringing up on the gray clay and coming to refusal on gravel.

No other boring taken on the bay north of this point has disclosed a condition so favorable to pile foundations. The nearest approach is Boring No. 40 taken off Hunter Point.

Borings Nos. 18 and 19 on Location No. 2 may be said to compare favorably with Boring No. 41, while Boring No. 20 is somewhat less favorable. Borings Nos. 34, 35 and 37 on Location No. 1-A are much less favorable for pile foundations while 38 is more favorable but not comparable with 41, because of the greater depth to a gravel stratum.

10. General description of borings.

The borings taken give a picture of the general foundation conditions to be found on San Francisco Bay between Locations Nos. 3 and 5. It is always desirable in the construction of a heavy bridge structure involving long spans such as are necessary to span San Francisco Bay, to found piers on solid material rather than piles, particularly so, if piles can not be driven to solid material such as rock, shale or deep gravel beds. Two of the five locations investigated afford such a foundation condition where heavy spans are necessary, viz, Locations

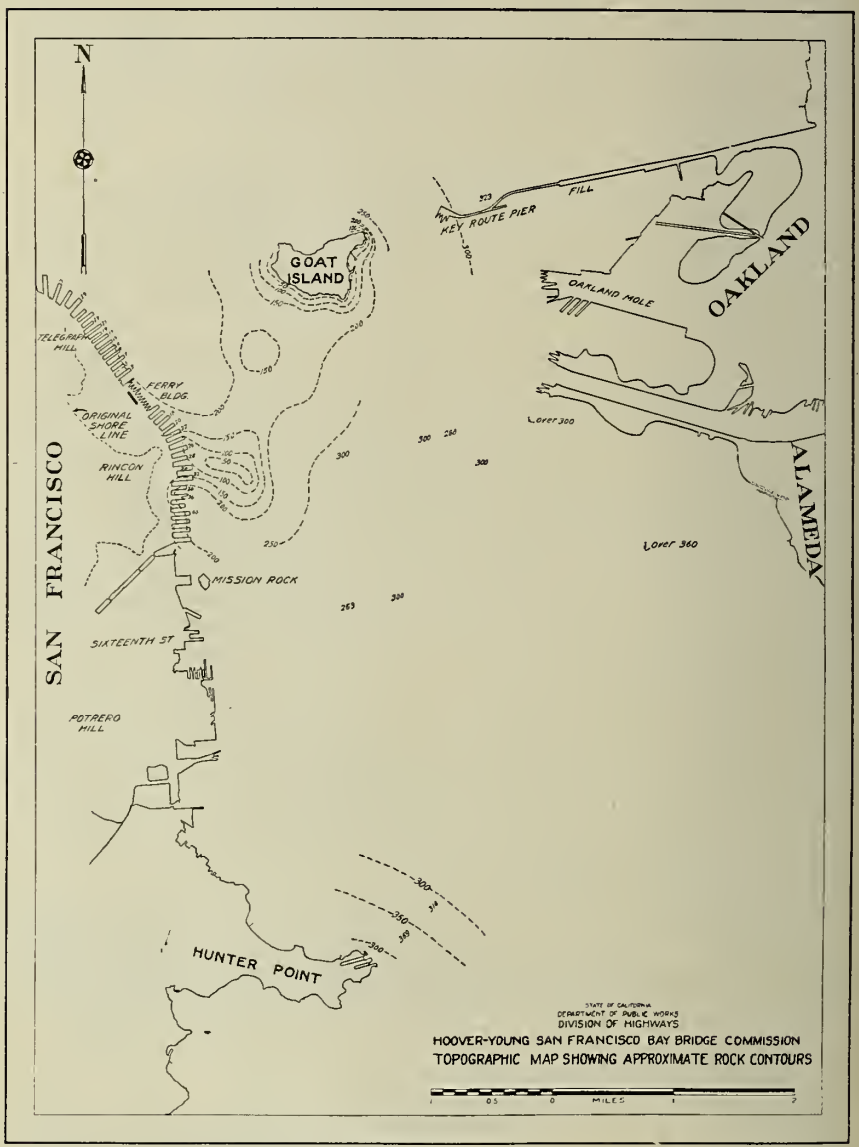

N
GOAT ISLAND
KEY ROUTE PIER
FILL
OAKLAND MOLE
OAKLAND
ALAMEDA
TELEGRAPH HILL
FERRY BLDG.
ORIGINAL SHORE LINE
RINCON HILL
MISSION ROCK
SIXTEENTH ST
POTRERO HILL
HUNTER POINT
SAN FRANCISCO
Lower 300
Lower 360
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
TOPOGRAPHIC MAP SHOWING APPROXIMATE ROCK CONTOURS
MILES

PLATE No. 19

Nos. 3 and 4. Of these Location No. 4 is the most favorable because of the lesser depths to shale.

Locations Nos. 1 and 1-A afford excellent foundations for some 3000 feet adjacent to the San Francisco shore. In fact the foundations are the most favorable of all for heavy piers over this distance. Approximately 3000 feet off shore, however, the shale surface drops off rapidly to depths beyond those practical for bridge foundations and for the remaining distance of 12,000 feet to the Alameda shore piers must depend either upon bearing on stiff sandy clay or strata of sand and gravel underlaid with clay or upon piles driven into strata of similar character.

Spans of 750 feet with a vertical clearance of 150 feet above water are required for a greater part of this distance. Spans of this character must be considered major structures and are subject to heavy vertical and lateral reactions. There is no doubt but that major vertical reactions can be sustained by pile foundations driven into material such as is present within reasonable depths on Locations Nos. 1 and 1-A. The question of sustaining lateral reactions in the softer strata encountered in the upper levels is a more serious question and require the use of battered piles.

In order to use battered piles, pier bases must be made larger and more expensive to afford clearance to drive the battered piles. Estimates indicate that it is actually less expensive to sink piers to the deeper strata without piles than to use a pier supported on piles driven to the same deeper strata for bearing. The lateral stability of a pier without piles is unquestionably much more satisfactory. On Location No. 2, for a distance of from 2000 to 3000 feet off the San Francisco shore, a very poor foundation condition exists. Long heavy spans resting on shale or rock would be required. Boring No. 21 shows rock to be 293 feet below the surface. It is not considered practicable to sink piers to this depth and for that reason further consideration of the line is dispensed with in this report.

The remaining portion of Location No. 2, from Alameda to a point 3000 feet off San Francisco, gives promise of good pile or pier foundations at a fairly reasonable depth for spans of 400 or 450 feet in length.

On Location No. 3 shale foundations can be obtained at extreme depths for the heavy piers between San Francisco and Goat Island. East of Goat Island the cantilever span adjacent to the island can be founded on shale. The remaining part of the structure is composed of 300 foot viaduct spans and can be safely supported on piles driven in sandy clay.

On Location No. 4 a high ridge of shale and sandstone extends from Pier 24 across the main channel to Goat Island. The rock slopes downward to the north and south from this line. It is on this location that the most satisfactory foundation throughout the full length of line can be obtained. All of the heavy piers under spans over 300 feet in length can be founded on shale or sandstone and the spans shorter than 300 feet on piles driven in sandy clay.

Location No. 5 would probably involve only one long span which would be required to rest on a pile foundation. The remaining part of the No. 5 line would consist of short low spans under which a pile foundation would be satisfactory. A general observation in studying

the boring results is that the southern portion of the area, covered by Location No. 5, is more suitable for pile foundations than are the northern locations and rock elevations are beyond the reach of practicable foundations without piles. The reverse conditions are true on the northern locations, where shale can be reached within a reasonable distance for all the heavy spans on Locations Nos. 3 and 4 and on part of Location No. 1, while pile foundations are less satisfactory.

Under heavy spans, whose weight is high above the supporting base, the lateral forces produced by earthquakes are very great. The forces may vary from very minor shocks to shocks so great that no structure would stand. The foundation that will stand the greatest overstress is therefore by far the most desirable. On the area covered by these borings the best material found within reasonable depth to meet this requirement is shale, and the best foundation conditions found on any line throughout its entire length are on Location No. 4.

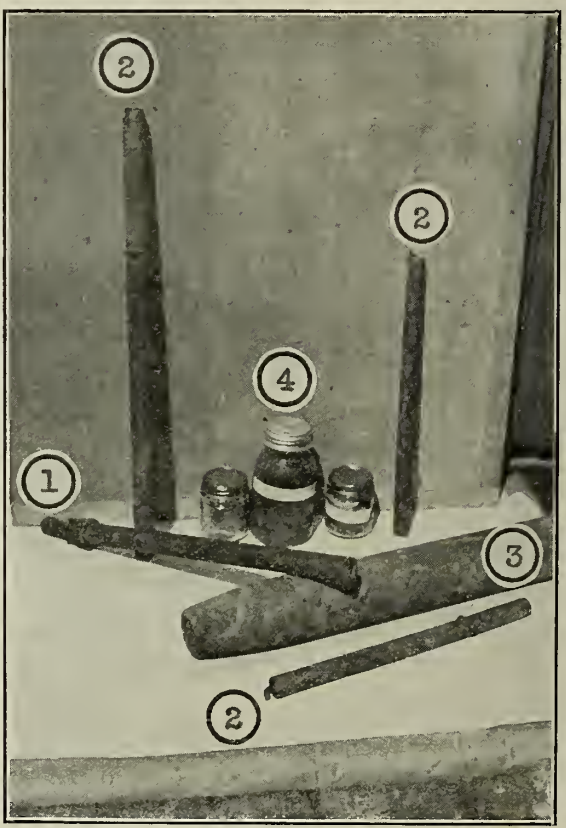


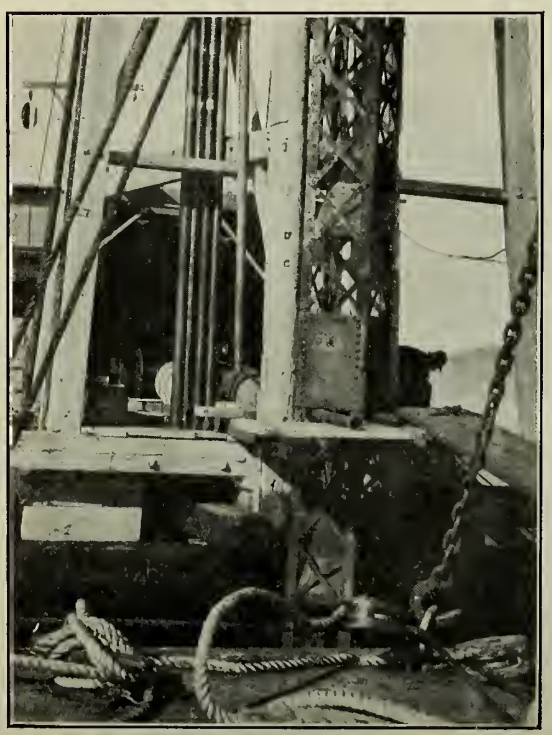
PLATE No. 20

1. Valve sampling device
2. Auger sampling device
3. Nozzle
4. Sample jars

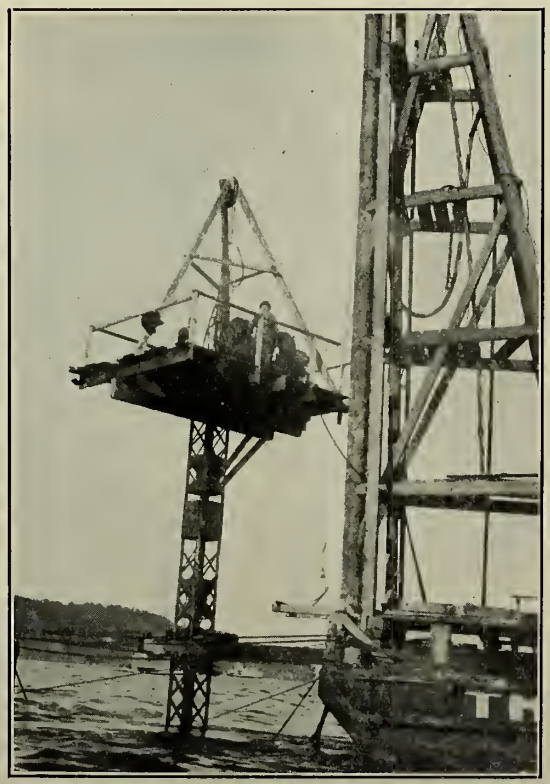
Diamond drilling at Boring No. 26

Diamond drilling machinery and platform

PLATE No. 21

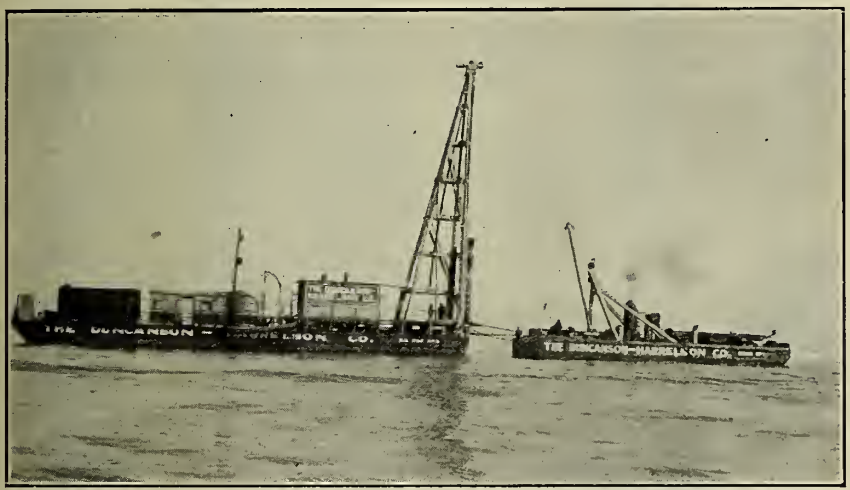


Bow of drill barge showing drill cage in leads with jet pipe at left ready to be lowered

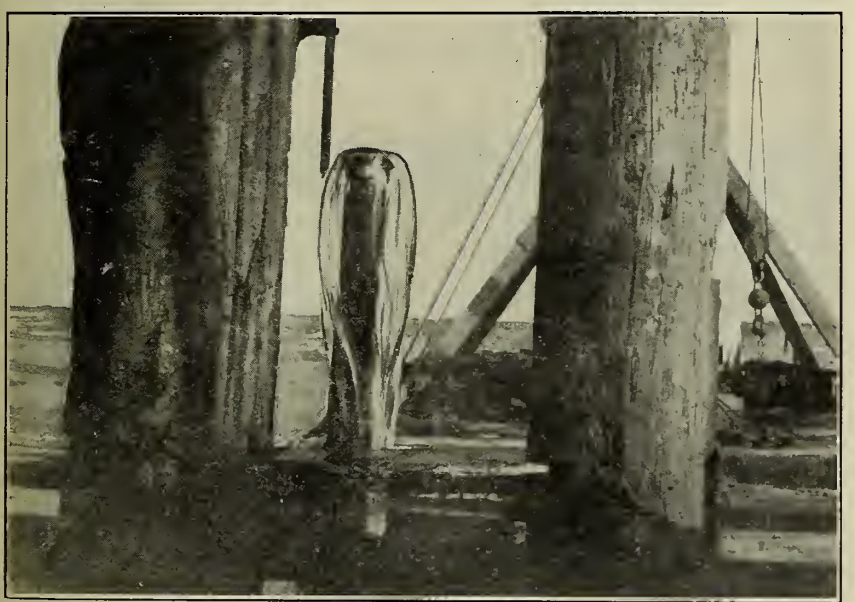


Diamond drilling at Boring No. 23

PLATE No. 22



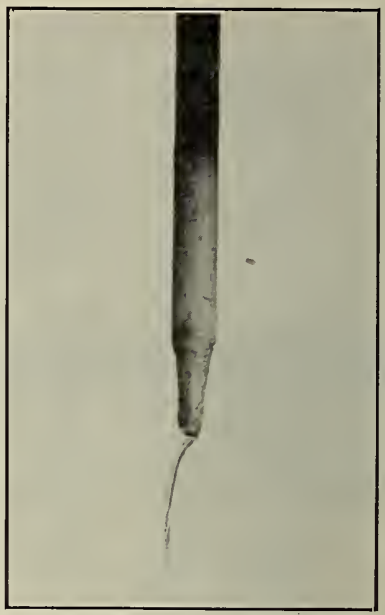
Barges in position for making wash boring at Boring No. 1



Artesian well at Boring No. 19 encountered at elevation –240

PLATE No. 23

Sample pipe being lowered to obtain samples



Sample pipe being raised after engaging sample

Cables emerging from Goat Island

PLATE No. 24

SECTION III

DESIGN DATA

1. Navigation clearances, general.

The general assumption as to vertical clearance is based upon the height of ships passing under the bridge in question. Reference is made to Chapter "C" of the 1927 report on "Harbor, Commerce and Ships," pages 31 to 39. Here a comprehensive statement, including mast and funnel clearances of the world's largest ships, will be found. It will be noted that the highest mast entering San Francisco Bay is 177.5 feet, and that the highest listed ship on record, which has not entered San Francisco Bay, is 228 feet.

2. Vertical clearance.

Study of the data listed seems to indicate that maximum vertical clearance for Locations Nos. 3 and 4 should be fixed at not less than 220 feet for at least a portion of the channel. Clearance at the dock on these two locations has been fixed at slightly over 171 feet above low water. These clearances will permit all listed ships, with one exception, to pass under the two center spans of these bridges. At the same time, all except two ships which have entered the harbor can pass under the bridge immediately adjacent to the dock line.

A study of zone distribution of ship traffic along the San Francisco water front indicates that 77.43 per cent of the traffic passes under Location No. 3 and 33.83 per cent under Location No. 4.

Location No. 1-A is proposed as having a clearance of 165 feet at high water under the central 600 feet of two 1700-foot spans adjacent to San Francisco. Clearance at the docks, as well as at the piers of the cantilever spans, is 150 feet above high water. Under the long series of 750-foot spans between the cantilever spans and the point at which it is necessary to break grade, the vertical clearance is held at 150 feet. From the break in grade, the clearance gradually decreases to only a few feet at the Alameda shore. An alternate plan anticipates a lift span of 300 feet, giving 225 feet vertical clearance.

No design layout is shown on Location No. 2, due principally to the fact that it is not believed practicable to attempt the deep foundations necessary at the San Francisco end of this location.

At Location No. 5 a single long span over the channel is probably sufficient for all navigation needs. A clearance of 150 feet above high water is proposed, with lessening clearances in each direction toward shore.

In the design studies, a tube has been considered extending from approximately Pier 18 in San Francisco to the northern edge of the Southern Pacific Oakland mole. The vertical clearance above the proposed top of tube is 55 feet below low water, beginning at a point 25 feet inside the pierhead line on the San Francisco side and extending 25 feet inside the pierhead line on the Oakland side, or a distance of 17,102 feet. From this point it rises to a clearance of 45 feet below low water at the Southern Pacific Oakland mole. The above clearance include five feet of fill over the top of tube.

3. Horizontal clearance.

The horizontal clearance at Locations Nos. 3 and 4 is largely established by economic span lengths. The total distance between San Francisco shore and Goat Island is approximately 8800 feet on either line. For the cantilever type of structure, this distance is economically divided into 4, 5 or 6 main spans, the respective span lengths being approximately 1700 feet, 1400 feet and 1175 feet, center to center of bearing shoes. From these spans it is necessary to deduct the space required for piers and pier protection to obtain the horizontal clearance for commerce. These resulting horizontal clearances for the respective span lengths are 1600 feet, 1300 feet and 1080 feet between pier protections. The shorter span is not considered sufficient and is, therefore, omitted in this report.

The relative costs of the 1700 foot and the 1400 foot span layouts over the main channel are as 425 is to 400. Computed over the entire project the ratio becomes approximately as 67 is to 65. Because of the advantage of the longer span to navigation, it is selected as the proper one to use.

For Location No. 1-A, span lengths for the two openings adjacent to San Francisco as shown on the proposed design are 1700 feet with 1580 feet clear between pier protections. The fixed spans to the Alameda shore are 750 foot spans with approximately 625 feet clear between pier protection structures.

If the long spans on the San Francisco end are reduced to 1400 feet with 1290 feet clear between pier protection structures and an additional 750 foot fixed span be added, the ratio of costs for the entire portion of the two structures over the open bay will be approximately as 49 is to 48.

A clearance of 1290 feet between pier protections in a location where large ships are backing out from their docks is believed to be the minimum.

In the proposed design, the longer spans are used as being the most desirable, viz, 1580 feet between pier protections. An alternate arrangement with 1400 foot spans is shown. The future development in pier and harbor facilities will in all probability be toward the south. The present water front northward to the Presidio is all but fully developed. With such future development, it will become more and more desirable to have the wide clearance at Location No. 1.

For Location No. 5, a single span of 1200 feet over the main channel, with a clear waterway of approximately 1100 feet between pier protections is proposed. Anchor spans of 450 feet are used on each side, with 300 foot deck approach spans. The 300 foot approach spans to the eastward descend on a 3 per cent grade to a low concrete structure toward the Alameda shore.

4. Roadway and interurban requirements.

The width of roadway and number of tracks required are among the most important questions to decide. In the 1927 report, the Engineers recommended a minimum roadway width of four traffic lanes and three interurban tracks. Their judgment was no doubt based upon the predicted traffic. Referring to the 1929 traffic survey and com-

paring it with the 1927 prediction, it will be noted that the traffic prediction for 1929 was exceeded in actual count by over 1,000,000 automobiles, or nearly 27 per cent.

A revised prediction now indicates that by 1940 more than 10,000,000 cars will cross the bay. If this prediction is exceeded by 25 per cent, as was the 1927 estimate, the actual count will be approximately 13,000,000 by 1940. The bridge will be only a few years old at that time.

A reasonable life for a bay crossing may be placed at 60 years. It is, of course, impossible to predict what the population of the bay district will be by that time. The increase over the last ten years has been between 25 and 30 per cent. Should such an increase continue for 30 years, the population will double. Such a prediction seems conservative. Table No. 15, page 74, gives the population of the bay district over a period of years.

Assuming that the automobile population will increase in the same ratio, there would be at least 20,000,000 cars crossing the bridge 25 to 30 years after its completion. It is admitted that the prediction of traffic 30 years into the future is more or less presumptious. However, in the design of a bridge such as the one in question, the engineer must make such an estimate. A ten year period is insufficient because of the longer life of the bridge. A period of 30 years, or one-half of the estimated life of the bridge, is taken. If the prediction for 30 years is correct and the roadways are designed for such a traffic, it may be expected that up to that time the bridge will be operating somewhat under capacity. After 30 years, and to the end of its life, the bridge will be operating somewhat over capacity. It is on such an assumption that the roadway width is designed.

Referring again to the traffic survey; the estimated peak hour per 1,000,000 vehicles is 500. For a traffic of 20,000,000 vehicles, a peak hourly traffic of 10,000 would be realized. The Maintenance Department of the Division of Highways estimates an hourly peak of 6150 vehicles for a traffic of 15,000,000 vehicles per year, 65 per cent of which will be in one direction. For 20,000,000 cars per year, the Maintenance Department's figure for peak load would be 8200 per hour, 65 per cent of which is in one direction or 5350 cars. This figure checks closely with our traffic survey. The capacity of one traffic lane is approximately 2000 cars per hour.

Designs and estimates for Locations Nos. 1, 3 and 4 are based on a roadway width of 56 feet between curbs. This roadway is divided into six traffic lanes. The two outside lanes are for slow moving vehicles and trucks and are each ten feet wide. The four inside lanes are each nine feet wide and are for fast traffic. The capacity of the four center lanes is therefore 2000 times 4; or 8000 cars per hour, which represents a yearly traffic of fast vehicles of 16,000,000 cars with peak travel equal in each direction. If consideration is given to the fact that during peak hours the traffic is approximately 65 per cent in one direction and 35 per cent in the other, the above figure of 16,000,000 is reduced to 12,300,000.

Assuming that trucks constitute 12 per cent of the total travel, the two outside lanes would carry 1,800,000 trucks. On this basis, the six traffic lane bridge has a capacity of 14,100,000 vehicles per year with-

out congestion. There can be no question but that a traffic of 14,000,000 will be reached within 15 years after the bridge is complete and that it will increase to a much larger number within the life of the bridge.

It is desirable to permit all classes of vehicular traffic to cross the bridge. For that reason slow speed traffic lanes are considered necessary.

The long spans on Locations Nos. 1, 3 or 4, require a distance between trusses greater than that required for four traffic lanes and approximately the distance required for six traffic lanes.

In view of the above considerations, the six traffic lane structure has been adopted for Locations Nos. 1, 3 and 4, and comparative estimates are made on that basis. Reference is made to Plate No. 45 for typical roadway cross section.

It will be noted that the plan suggested is flexible in its usage. The minimum interpretation in regard to highway capacity is six traffic lanes on the upper deck and four car tracks on the lower deck. The maximum interpretation, with provision for two operating and an emergency passing track for interurban cars, is six fast traffic lanes on the upper deck and two truck lanes on the lower deck. Should the time come when commuter traffic could be dispensed with or carried on passenger buses, the trucks could be removed and the total capacity for vehicular traffic increased to six lanes on the upper deck and six lanes on the lower deck.

On Location No. 5, due to the much smaller amount of traffic which may be expected, the roadway width has been reduced to four traffic lanes.

A study of the commuter traffic has disclosed that the anticipated increase has not materialized.

(Reference is made to Section I, Traffic Survey.)

The Board of Engineers in the 1927 report recommend three tracks. In view of the traffic studies, it is believed that three tracks are sufficient for many years, unless it is found desirable to have two tracks each for two operating companies. The contemplated width of bridge provides room for four tracks and sidewalks on the lower deck on Locations Nos. 1, 3 and 4. No provision is made for interurban cars on Location No. 5.

5. Grades.

The question of what limiting grades to use is one of great importance. Too steep grades greatly reduce the utility of the structure, but on the other hand the use of flatter grades than are necessary greatly increases the construction cost of approach structures. Several maximum grades used in major structures in various parts of the country are cited:

The Holland Tubes under the Hudson River have a maximum descending grade of 4.06 per cent and a maximum ascending grade of 3.80 per cent for a distance of approximately 1500 feet. Bicycles, hand and push carts, wheelbarrows, double-deck buses, horse drawn vehicles, vehicles having axle loads in excess of 12 tons or any vehicle which is so loaded or constructed so as to seriously retard traffic are not allowed to enter the tunnel.

The Oakland Estuary Tube has a maximum grade of 4.59 per cent for approximately 1500 feet. Trucks which can not negotiate this grade at 5 miles per hour are not supposed to enter the tube. Experience has shown that trucks which can not meet this requirement do enter the tube and faster trucks and cars are greatly delayed.

The Philadelphia-Camden Bridge across the Delaware River has 3½ per cent as a maximum grade of highway. Many of the Hudson River bridges have grades of 3½ per cent or less.

It is not desirable to limit in any way the passage of trucks across a San Francisco Bay crossing. At the same time it is very desirable to speed up truck travel as much as possible.

A general study of the grade problem indicates that a 3½ per cent ascending grade for highway traffic and a 3 per cent ascending grade for interurban cars are approximately the maximum economic grades from a point of view of combined construction and operating costs. These limiting grades are, therefore, used as maxima in the designs and comparative estimates.

6. Loading and stresses.

For data on loading and stresses reference is made to Plate No. 38 of this report.

Earthquake Stress Provisions:

Provision has been made in the design of the substructure and superstructure to resist the lateral and vertical forces of earthquake vibration.

For the substructure, allowance has been made for a force of 10 per cent of gravity acting in any direction at the center of mass of the entire structure.

For the superstructure, allowance has been made for a force of 6 per cent of gravity acting in any direction at the centers of mass. The unit stresses used in the various parts of the structure for a combination of earthquake and dead load forces are 30 per cent greater than the normal unit stresses.

The foundation material encountered is shale or sandstone for all heavy piers on Locations Nos. 3 and 4, and is capable of sustaining a safe load of 25 to 30 tons per square foot. Maximum foundation pressures as designed do not exceed 25 tons per square foot on shale or sandstone.

As a comparison, the allowances for earthquake stresses recommended by the committee appointed by the American Society of Civil Engineers are given, as follows:

For structures founded on material capable of sustaining a safe load of one ton per square foot, 8 per cent of gravity.

For structures founded on material capable of sustaining a safe load of 2 tons per square foot, 6 per cent of gravity.

For structures founded on material capable of sustaining 3 tons per square foot, 5½ per cent of gravity.

For structures founded on material capable of sustaining 4 or more tons per square foot, 4 per cent of gravity.

The material upon which the piers under consideration would rest is capable of sustaining safely a load of 30 tons per square foot. An allowance of 10 per cent of gravity has been made, which is 2½ times

that recommended by the Committee on a very inferior bearing material.

The provision for earthquake stress may therefore be considered very conservative.

7. General description of structures.

(a) *Location No. 1.*

The structure contemplated is a double deck bridge with provision for six traffic lanes for highway traffic on the upper deck and four interurban tracks and sidewalks on the lower deck.

The main structure across the bay consists of two 1700-foot spans adjacent to the San Francisco shore, providing a clear waterway of 1580 feet and a vertical clearance above high water of 165 feet in the channel. An alternate plan contemplates the use of two 1400-foot spans with 1290-foot clear waterway. The remaining structure across the bay consists of either twelve or thirteen 750-foot fixed spans providing 150 feet vertical and 625 feet horizontal clearance for 6786 feet; whence it descends on a 3 per cent grade for 2260 feet. From this point four 300-foot spans extend to the Alameda shore, from which a concrete structure carries traffic to the grade of the Alameda Mole. The route then travels along the Alameda Mole for approximately 3000 feet where it swings on a curved and descending grade through tubes under the estuary, to a plaza in Oakland. Interurban tracks require two tubes and highway traffic two tubes. No plan of the line is shown.

(b) *Location No. 1-A.*

Location No. 1-A contemplates a structure across the bay similar in all respects to Location No. 1 with the exception that its San Francisco end begins at Pier 32 (Line No. 1 begins at Pier 34), and its center line intersects the Alameda shore somewhat south of Location No. 1. From the Alameda shore the grade descends to a subway entrance at the west boundary of the Alameda Airport. From this point the highway and interurban run under the airport, estuary and Southern Pacific track to the same plaza in Oakland as for Location No. 1. Plate No. 39 is a plan of this location.

(c) *Location No. 1-B.*

Location No. 1-B is similar in all respects to Location No. 1-A except that 1-B cuts through the Alameda Airport at grade, eliminating the long surface subway under the Airport. Location No. 1-B is the same in general character as Location No. 1, except that it affords a much better alignment and somewhat cheaper foundations for the bay section.

(d) *Location No. 1-C.*

Location No. 1-C contemplates the same main structure across the bay as does No. 1-A. The grade near the Alameda shore is, however, held somewhat higher than Location No. 1-A. From the Alameda shore the highway and tracks run on a low double deck viaduct for a short distance; then rise on a 3 per cent grade and cross over the estuary on a bridge spanning the entire distance between harbor lines

with 165-foot vertical clearance above high tide. The grade then descends, passing over the Southern Pacific yards, to Oakland.

Of the four lines Locations Nos. 1, 1-A, 1-B and 1-C, Locations Nos. 1 and 1-A offer the least damage to the Alameda Airport. Locations Nos. 1-B and 1-C virtually render the airport useless and would probably cause its abandonment.

The problem of either going over or under the Oakland Estuary from any of the Locations Nos. 1, 1-A, 1-B or 1-C is one of the most difficult and expensive to solve satisfactorily. If the Alameda Airport is to be preserved in an operative condition Location No. 1-A seems to be the most logical, but at the same time the most expensive. If the airport can be abandoned and if permission can be obtained to cross the estuary with a bridge with 165 feet vertical clearance, then Location No. 1-C is probably more desirable.

Direct highway and interurban connections to Alameda are made by way of the Alameda Mole.

The distribution of traffic in San Francisco is the same for Locations Nos. 1, 1-A, 1-B and 1-C. Automobiles are carried on Harrison street to a plaza located between Fifth and Sixth streets. A ramp is constructed from the bridge at First street, leading to the Embarcadero. Its principal function is to provide an outlet for truck traffic to the water front. Interurban traffic turns north on First street to a loop as shown. It is planned to discharge main line railroad passengers coming from or going to Oakland at the First street loop station. An alternate plan is to establish a depot on Rincon Hill.

(e) *Location No. 4.*

The structure proposed is a double-deck bridge carrying six traffic lanes of highway travel on the upper deck and four interurban tracks on the lower deck. Sidewalks are provided on the lower deck.

An alternate arrangement of traffic is shown to carry six traffic lanes of fast highway traffic on the upper deck and two truck lanes on the lower deck with two interurban tracks in the center and an emergency passing track set in the pavement of either one or both of the truck lanes. Sidewalks in this arrangement are placed above the upper deck.

The main structure across the bay between San Francisco and Goat Island consists of four 1700-foot cantiveler spans with 600-foot anchor spans at each end. The vertical clearance above highwater is 168 feet at the dock and 214 feet under the suspended spans of the two center spans. The horizontal clear waterway is 1600 feet between pier protections. Goat Island is crossed by a cut, fill and viaduct. Adjacent to the east shore of Goat Island a 720-foot deck cantilever span is used to span the deep-water channel. The remaining portion of the structure to the Oakland shore consists of twenty-one 300-foot steel deck spans.

The highway traffic is distributed by two roads to Yerba Buena avenue and Twenty-second street, each passing through a subway under the Southern Pacific tracks. Railway connections are made directly into the present track systems of the Key Route and Southern Pacific railroads.

Highway traffic in San Francisco is carried on Harrison street to a plaza located between Fourth and Fifth streets and Folsom and Bryant streets. A ramp for truck and automobile traffic takes off

the approach viaduct at First and at Essex streets and discharges traffic to the Embarcadero and the water front. Interurban railroad traffic turns off the approach viaduct on First street and runs over an elevated loop on First street to Minna street; from which it proceeds west on Minna street to Sixth street; south on Sixth street to Clementina street, then east to First street.

Four loop stations are contemplated. In the estimates given it is proposed to receive and discharge main line railroad passengers to and from the main line railroad in Oakland at the First street loop station. It may be found necessary, however, to establish a terminal station on Rincon Hill for this purpose. Connection to such a station can easily be made from the bridge.

(f) *Location No. 3.*

The structure contemplated on Location No. 3 is in many respects similar to the proposed structure on Location No. 4. The main bridge structure between Goat Island and Telegraph Hill is practically identical with the structure on Location No. 4 between Goat Island and Rincon Hill, with the exception that foundations on Location No. 3 average approximately 40 feet deeper than on Location No. 4. The distance from shore to shore is practically equal on Locations Nos. 3 and 4. The section over Goat Island is very similar in type and cost of construction to that on Location No. 4.

The bridge structure from Goat Island to Oakland is identical with Location No. 4. The traffic distribution in Oakland is identical with Location No. 4. The distribution of traffic to San Francisco, as may be seen on Plate No. 42, is to the Telegraph Hill District rather than the Rincon Hill District.

A distribution of traffic from Location No. 3 equal in service to the scheme used for Locations 1 and 4 is difficult and expensive. The topography of the city in the vicinity of Telegraph Hill and the area to the south and west is extremely irregular as to grade. The streets generally are much narrower than those south of Market street.

(g) *Location No. 5.*

The structure contemplated on Location No. 5 is a four-traffic-lane highway bridge with no provision for interurban electric trains. It consists of a series of 300-foot spans leading from Hunter Point to a single cantilever channel span of 1400 feet. The channel span provides a vertical clearance of 150 feet above high tide and a horizontal clearance of 1200 feet between fenders. From the channel span the grade descends to the eastward on a 3 per cent grade over 300-foot deck spans to a reinforced concrete structure extending to Webster street in Alameda.

To carry the increased traffic from this bridge, it would be necessary to construct an additional two-lane tube under the Oakland Estuary. The cost of such a tube is included in the cost estimates.

(h) *Tube Line.*

The structure contemplated on the tube line is a twin three traffic lane tube for highway traffic only. This line extends from the foot of Folsom street in San Francisco to the foot of Seventh street in Oakland. It is the most direct line between traffic centers.

It is proposed to construct these tubes by the open trench method. The general design of tubes is made on the assumption that when completed they must rely entirely upon their own weight to stay in position. In this respect they differ from the tubes under the Oakland Estuary and because of this fact are relatively much more expensive. It is presumed that in the future it may be found necessary to dredge deep channels for navigation at various points in the bay and across the line which the tubes traverse. If this condition is to be met, the tubes must be able to remain submerged under their own weight with only a few feet of covering over the crown. To facilitate construction, reduce drydock expense, make it possible to construct long sections with fewer joints and to obtain maximum insurance against leaks from slight distortions due to lateral stresses, a double structural steel shell filled with concrete is used. Copper bearing steel is utilized in the outer shell to resist corrosion. Plates Nos. 48, 49, 50 and 51 of the tube line are shown.

SECTION IV

ECONOMIC STUDIES

1. Estimates.

Estimates of costs for structures on Locations Nos. 1, 3 and 4 are based on designs of equivalent service value, i.e., six lanes of highway traffic on the upper deck and four interurban tracks and sidewalks on the lower deck.

An exception to the above is the single deck highway bridge on Location No. 4 and the tube line. These two structures provide for six lines of highway traffic only.

The following tables, Nos. 36 to 42, inclusive, are cost estimates. All total and sectional cost items include, in addition to the actual construction cost, an item of 5 per cent for engineering and legal service, 5 per cent for contingencies and 12 per cent for interest charges during construction.

TABLE No. 36. LOCATIONS 1, 1-A, 1-B—ESTIMATES

All Double Deck Structures

Item No.	Description	Cost, No. 1-A	Cost, Nos. 1 and 1-B
1	San Francisco Plaza	$253,000	$253,000
2	San Francisco 1st to 5th streets	944,000	944,000
3	San Francisco, 1st to Anchor Arm	1,222,000	1,222,000
4	San Francisco Railroad Loop	2,550,000	2,550,000
5	San Francisco Highway Loop	946,000	946,000
6	Main Channel	21,237,000	21,237,000
7	Twelve 750-foot spans	31,284,000	31,284,000
8	Alameda 300-foot spans	2,438,000	2,438,000
9	Alameda R. C. Viaduct	839,000	839,000
10	Main tubes	48,740,000	37,652,000
11	Alameda connections	1,188,000	1,188,000
12	Lighting and traffic control	608,000	608,000
	Sub-totals	$112,248,000	$101,161,000
	Property, 1-A and 1	3,750,000	4,000,000
	Totals, Location 1-A Say and 1 Say	$116,250,000	$105,500,000
	Property, 1-B		4,250,000
	Total, Location 1-B Say		$105,750,000

Includes 10% engineering and contingencies and 12% for interest during construction.

TABLE No. 37. LOCATION No. 1-C ESTIMATE

Item No.	Description	Length in feet	Cost
1	San Francisco Plaza		$253,000
2	San Francisco, 1st to 5th streets	3,600	944,000
3	San Francisco, 1st to Anchor Arm	1,588	1,222,000
4	Railroad Loop	12,580	2,550,000
5	Highway Loop	750	946,000
6	Main channel	5,108	21,237,000
7	750-foot spans	10,556	35,710,000
8	300-foot spans	11,160	19,730,000
9	Estuary span	1,800	6,788,000
10	Oakland approaches	3,300	757,000
11	Alameda connections	1,300	370,000
12	Lighting and traffic control		169,000
	Sub-total		$90,676,000
	Say		$91,000,000
	Property		4,000,000
	Total		$95,000,000

Includes 10% engineering and contingencies and 12% for interest during construction.

TABLE No. 38. STRUCTURE LOCATION No. 3

Estimate Double Deck Structure. Six Traffic Lanes Upper Deck; Four Tracks Lower Deck

Item No.	Description	Length in feet	Cost
1	San Francisco Plaza	345	$54,065
2	San Francisco Plaza to Montgomery St.	2,500	432,459
3	San Francisco Montgomery St. to Anchor Arm	1,178	1,871,027
4	San Francisco R.R. Loop	15,676	3,400,209
5	West Channel	8,600	50,196,226
6	Goat Island	3,935	2,753,675
7	East Channel	8,700	14,803,359
8	Key Route Mole, Yerba Buena St.	13,400	626,417
9	Key Route Mole, 22nd St.	11,750	571,983
10	Key Route Mole, R.R.	16,825	567,648
	Sub-total		$75,277,068
	Say		$75,500,000
	Property		3,750,000
	Total		$79,250,000

Estimate includes lighting and signals.
Includes 10% engineering and contingencies and 12% for interest during construction.

TABLE No. 39. STRUCTURE LOCATION No. 4

Estimate Double Deck Structure. Six Traffic Lanes Upper Deck; Four Tracks, Lower Deck

Item No.	Description	Length in feet	Cost
1	San Francisco Plaza		$253,000
2	1st to 4th Sts.	2,892.5	757,000
3	1st to Anchor Arm	2,005.5	1,542,700
4	Interurban Loop (S. F.)	12,333.7	2,505,600
5	Highway Loop (S. F.)	6,935.0	871,300
6	West Channel (Br.)	8,600.0	41,815,000
7	Goat Island	3,585.0	2,973,100
8	East Channel	8,700.0	15,099,400
9	Key Route Mole, Yerba Buena St.	13,400.0	1,549,200
10	Key Route Mole, 22nd St.	11,750.0	572,000
11	Key Route Mole, R.R.	16,825.0	567,600
	Sub-total		$68,505,900
	Say		$68,600,000
	Property		3,400,000
	Total		$72,000,000

Table contains item for lighting and traffic control.
Includes 10% engineering and contingencies and 12% for interest during construction.

TABLE No. 40. STRUCTURE LOCATION No. 4

Estimate Single Deck Highway. Six Traffic Lanes

Item No.	Description	Length in feet	Cost
1	San Francisco Plaza		$256,800
2	San Francisco, 1st to 4th Sts.	2,892.5	855,500
3	San Francisco, 1st to Anchor Arm	2,005.5	1,025,400
4	San Francisco Highway Loop	6,935.0	972,100
5	West Channel	8,600.0	31,445,900
6	Goat Island	3,585.0	1,670,700
7	East Channel	8,700.0	10,846,900
8	Key Route Mole and Yerba Buena St.	13,400.0	1,577,900
9	Key Route and 22nd St.	11,750.0	608,100
	Sub-total		$49,259,300
	Say		$49,500,000
	Property		2,000,000
	Total		$51,500,000

Table contains provision for lighting and traffic control.
Includes 10% engineering and contingencies and 12% for interest during construction.

TABLE No. 41. ESTIMATE TUBE LINE

Two Parallel Tubes—Three Traffic Lanes Each Tube

Item No.	Description	Length in feet	Cost
1	San Francisco Plaza, 3rd to 2nd Sts.		$251,000
2	Double Box Section, 2nd to Beale Sts.	1,800	2,079,000
3	Double Arch Section, Beale to Stuart Sts.	1,030	2,475,000
4	First St. exit	450	95,000
5	Beale St. entrance and exit	1,350	358,000
6	Spear St. entrance	1,140	1,275,000
7	Floated sections	19,380	61,176,000
8	Oakland approach and Toll House		1,077,000
9	Ventilation buildings and fenders		12,210,000
10	Electrical, ventilation and pumping equipment		3,500 000
	Sub-total		$84,496,000
	Say		$84,760,000
	Property		2,240,000
	Deficit during first years of operation		9,000,000
	Total		$96,000,000

Includes 10% engineering and contingencies and 12% for interest during construction.

TABLE No. 42. STRUCTURE LOCATION No. 5

Estimate Single Deck Structure. Four Traffic Lanes

Item No.	Description	Length in feet	Cost
1	Concrete approach highway, 40 feet wide, San Francisco side	3,435	$130,680
2	Steel structure over navigable channel	2,200	2,904,000
3	Two anchor piers and two main piers, including pier protection		2,420,000
4	Sixty 300-foot steel deck spans	18,000	7,260,000
5	Fifty-eight steel towers, including foundations	3,480	10,400,000
6	One hundred sixty-five 40-foot reinforced concrete spans on concrete piles	6,600	1,573,000
7	Tube under estuary	4,400	5,440,000
8	Property		100,000
			$30,227,680
	Say		$30,000,000

Includes 10% engineering and contingencies and 12% for interest during construction.

2. Income, expense and bond retirement.

(a) *Locations 1, 3 and 4.*

Referring to Section I, Traffic Survey, it will be noted that the expected income is practically equal on Locations Nos. 1, 3 and 4. Table No. 14, Section I, was compiled in January of this year. Since that date the 1930 census has been completed. It has been found that the estimated population of San Francisco and Alameda counties is somewhat less than the prediction. Populations for ten-year periods are shown in Table No. 15, Section I. It has been found that the per cent of increase in population from 1880 to 1930 has been practically uniform, the average rate being 3.06 per cent per year.

From Table No. 14 it is found that the average ratio of annual increase in cars per 1000 population is 2.73 per cent. The estimated population of San Francisco and Alameda counties for January 1, 1930, is now 1,126,000 as against 1,257,000 estimated in Table No. 14. Assuming a bridge will be completed in 1937, and applying a 3 per cent yearly increase in population, it is found that the population will then be 1,386,000 on January 1, 1937, instead of 1,644,000, as in Table No. 14.

The auto registration for San Francisco and Alameda counties for 1929 is 297,875 cars, and the average rate of increase for five years has been 5.8 per cent per annum. Assuming that this rate of increase will continue to 1937, the auto registration will be 470,000 and the cars per 1000 of population will be 339. If we apply the same increase, i.e., 5.8 per cent annually to the number of car trips we arrive at the figure of 7,070,000 for 1937.

The history of all bridge projects has been that a marked increase in auto traffic is experienced when the added facilities of a bridge are made available. A conservative estimate of this increase is believed to be 25 per cent. Applying this increase in 1937, we arrive at a traffic of 8,850,000 cars in 1938. For 1939 and 1940 a 5.8 per cent yearly increase brings the total to 9,900,000 cars, which is a lower figure than that shown in Table No. 14. These figures are given to show an alternate method of arriving at the 1940 figure, and is considered very conservative. Therefore, as a basis for computing income, a figure of 10,000,000 is taken for the year 1940.

To compute the income beyond 1940, the rate of increase is reduced to the population increase ratio, assumed at 3 per cent per annum, which, as before stated, is the average population increase ratio over the last 50 years.

For vehicular passengers the average number per car is held at two persons. On this basis the following income tables are made for a period of years sufficient to retire bonds and accumulate a reserve; the reserve being sufficient in each case to maintain the structure until about 1990.

Tables Nos. 43, 44, 45 and 46 are computed for Locations Nos. 1 and 4. No table is shown for Location No. 3 on account of its similarity to Location No. 4.

All income tables are computed on the basis that bonds can be sold at 6 per cent, and reserves can be invested during the period of bond payment at 3 per cent. Reserve for maintenance after bonds are retired is computed at an investment rate of 4 per cent. As a basis for com-

puting gross income on Locations Nos 1, 3 and 4, 80 per cent of the total highway traffic crossing the bay is taken as being diverted to the bridge until 1947, and 85 per cent thereafter. Tables based on three rates of toll are given for Location No. 4. All other tables are for the present toll rates.

(b) *Location No. 5.*

As a basis for computing income on Location No. 5, 40 per cent of the entire highway traffic crossing the bay is taken as being diverted to the bridge. Reference is made to Section I-B, Article 2, Movements between San Francisco and East Bay by ferries. Table No. 48 shows the gross and net income; operating cost and bond retirement computed on the same general basis as those for Locations Nos. 1, 3 and 4.

(c) *Tube Line.*

As a basis of computing income on the tube line, highway traffic only is considered and is taken as 80 per cent to 1947 and 85 per cent thereafter, as on Locations Nos 1, 3 and 4. Table No. 47 gives the expected traffic, gross and net income, cost of operation and bond retirement for a period of years sufficient to retire the bonds and accumulate the desired reserve for maintenance and operation.

Table No. 43

Location No. 1-C

Based on Diversion of 80% of Total Traffic to Bridge for First Ten Years, 85% Thereafter
Bond Issue $95,000,000 retired in 22 Years Leaving $10,756,400 Reserve

GROSS AND NET INCOME AND AMORTIZATION USING PRESENT TOLL RATES

YEAR	GROSS INCOME	YEARLY OPERATION	BOND INTEREST	TOTAL YEARLY COST	NET INCOME	RESERVE	BOND RETIREMENT
1938	$ 6,654,000	$ 730,000	$ 5,700,000	$ 6,430,000	$ 224,000	$ 224,000	$
1939	7,005,000	730,000	5,700,000	6,430,000	581,700	805,700	
1940	7,409,000	740,000	5,700,000	6,440,000	993,200	1,798,900	
1941	7,598,000	740,000	5,700,000	6,440,000	1,212,000	3,010,900	
1942	7,798,000	750,000	5,700,000	6,450,000	1,438,300	4,449,200	
1943	8,005,000	760,000	5,700,000	6,460,000	1,678,500	6,127,700	
1944	8,228,000	770,000	5,700,000	6,470,000	1,941,800	8,069,500	
1945	8,447,000	780,000	5,700,000	6,480,000	2,209,100	10,278,600	
1946	8,673,000	790,000	5,700,000	6,490,000	2,491,400	12,769,900	
1947	9,415,000	800,000	5,700,000	6,500,000	3,298,100	1,068,000	15,000,000
1948	9,669,000	810,000	4,800,000	5,610,000	4,091,000	5,159,100	
1949	9,931,000	820,000	4,800,000	5,620,000	4,465,800	9,624,800	
1950	10,211,000	830,000	4,800,000	5,630,000	4,869,700	4,494,600	10,000,000
1951	10,489,000	840,000	4,200,000	5,040,000	5,583,800	10,078,400	
1952	10,775,000	850,000	4,200,000	5,050,000	6,027,400	6,105,800	10,000,000
1953	11,081,000	860,000	3,600,000	4,460,000	6,804,200	2,910,000	10,000,000
1954	11,407,000	870,000	3,000,000	3,870,000	7,624,300	10,534,300	
1955	11,698,000	880,000	3,000,000	3,880,000	8,134,000	3,668,300	15,000,000
1956	12,020,000	890,000	2,100,000	2,990,000	9,140,000	2,808,300	10,000,000
1957	12,352,000	900,000	1,500,000	2,400,000	10,036,200	2,844,600	10,000,000
1958	12,695,000	910,000	900,000	1,810,000	10,970,300	3,814,900	10,000,000
1959	13,047,000	920,000	300,000	1,220,000	11,941,400	10,756,400	5,000,000
					Reserve	$ 10,756,400	$ 95,000,000

Table No. 44

Location No. 4

Based on a Diversion of 80% of Total Transbay Traffic to Bridge for First 10 Years; 85% Thereafter
Bond Issue $72,000,000 Retired in 16 Years Leaving $10,517,000 Reserve

GROSS AND NET INCOME AND AMORTIZATION USING PRESENT TOLL RATES

YEAR	GROSS INCOME	YEARLY OPERATION	BOND INTEREST	TOTAL YEARLY COST	NET INCOME	RESERVE	BOND RETIREMENT
1938	$ 6,654,000	$ 630,000	$ 4,320,000	$ 4,950,000	$ 1,704,000	$ 1,704,000	$
1939	7,005,000	630,000	4,320,000	4,950,000	2,106,100	3,810,100	
1940	7,409,000	640,000	4,320,000	4,960,000	2,563,300	6,373,400	
1941	7,598,000	640,000	4,320,000	4,960,000	2,829,200	9,202,600	
1942	7,798,000	650,000	4,320,000	4,970,000	3,104,100	12,306,700	
1943	8,005,000	660,000	4,320,000	4,980,000	3,394,200	15,700,900	
1944	8,228,000	670,000	4,320,000	4,990,000	3,709,000	19,409,900	
1945	8,447,000	680,000	4,320,000	5,000,000	4,029,300	23,439,200	
1946	8,673,000	690,000	4,320,000	5,010,000	4,366,200	27,805,400	
1947	9,415,000	700,000	4,320,000	5,020,000	5,229,200	3,034,600	30,000,000
1948	9,669,000	710,000	2,520,000	3,230,000	6,530,000	9,564,600	
1949	9,931,000	720,000	2,520,000	3,240,000	6,977,900	6,542,600	10,000,000
1950	10,211,000	730,000	1,920,000	2,650,000	7,757,300	4,299,800	10,000,000
1951	10,489,000	740,000	1,320,000	2,060,000	8,558,000	2,857,800	10,000,000
1952	10,775,000	750,000	720,000	1,470,000	9,390,700	2,248,600	10,000,000
1953	11,081,000	760,000	120,000	880,000	10,277,200	10,517,000	2,000,000
To 1990 - Average Maintenance and Operation 1954 to 1990 Inc. $600,000 per Annum.					Reserve	$10,517,000	$ 72,000,000

Reserve 1953 Invested at 4% Will Be Exhausted in 1990.

Table No. 46

Location No. 4

Traffic Stimulated 5% By Reduction of Tolls
Tolls 50¢ For Passenger Cars and 10% Reduction on Trucks and Commodities
Bonds Retired in 18 Years with $13,543,000 Reserve

GROSS AND NET INCOME AND AMORTIZATION USING REDUCED TOLLS

YEAR	GROSS INCOME	YEARLY OPERATION	BOND INTEREST	TOTAL YEARLY COST	NET INCOME	RESERVE	BOND RETIREMENT
1938	$ 6,178,000	$ 640,000	$ 4,320,000	$ 4,960,000	$ 1,218,000	$ 1,218,000	$
1939	6,497,000	640,000	4,320,000	4,960,000	1,573,500	2,791,500	
1940	6,844,000	650,000	4,320,000	4,970,000	1,957,700	4,749,200	
1941	7,015,000	650,000	4,320,000	4,970,000	2,187,500	6,936,700	
1942	7,198,000	660,000	4,320,000	4,980,000	2,426,100	9,362,800	
1943	7,387,000	670,000	4,320,000	4,990,000	2,677,900	12,040,700	
1944	7,592,000	680,000	4,320,000	5,000,000	2,953,200	14,993,900	
1945	7,791,000	690,000	4,320,000	5,010,000	3,230,800	18,224,700	
1946	7,997,000	700,000	4,320,000	5,020,000	3,523,700	21,748,400	
1947	8,220,000	710,000	4,320,000	5,030,000	3,842,500	1,590,900	24,000,000
1948	8,908,000	720,000	2,880,000	3,600,000	5,355,700	6,946,600	
1949	9,147,000	730,000	2,880,000	3,610,000	5,745,400	2,692,000	10,000,000
1950	9,404,000	740,000	2,280,000	3,020,000	6,464,800	9,156,800	
1951	9,658,000	750,000	2,280,000	3,030,000	6,902,700	1,059,500	15,000,000
1952	9,919,000	760,000	1,380,000	2,140,000	7,810,800	8,870,300	
1953	10,199,000	770,000	1,380,000	2,150,000	8,315,100	2,185,400	15,000,000
1954	10,476,000	780,000	480,000	1,260,000	9,281,600	3,467,000	8,000,000
1955	10,762,000	790,000	0,000	790,000	10,076,000	13,543,000	
					Reserve	$ 13,543,000	$ 72,000,000

Table No. 46

Location No. 4

Based on a Diversion of 80% of Total Transbay Traffic to Bridge For First 10 Years; 85% Thereafter

Traffic Stimulated 10% Over Traffic Forcasted in Table No. 44 by Reduction of Tolls; Tolls 40¢ for Passenger Cars and 20% Reduction Trucks and Commodities. $72,000,000 Bonds Retired in 20 Years Leaving $11,384,400 Reserve.

GROSS AND NET INCOME AND AMORTIZATION USING REDUCED TOLLS

YEAR	GROSS INCOME	YEARLY OPERATION	BOND INTEREST	TOTAL YEARLY COST	NET INCOME	RESERVE	BOND RETIREMENT
1938	$ 5,592,000	$ 650,000	$ 4,320,000	$ 4,970,000	$ 622,000	$ 622,000	$
1939	5,878,000	650,000	4,320,000	4,970,000	926,700	1,548,700	
1940	6,183,000	660,000	4,320,000	4,980,000	1,249,500	2,798,200	
1941	6,334,000	660,000	4,320,000	4,980,000	1,437,900	4,236,100	
1942	6,497,000	670,000	4,320,000	4,990,000	1,634,100	5,870,200	
1943	6,664,000	680,000	4,320,000	5,000,000	1,840,100	7,710,300	
1944	6,847,000	690,000	4,320,000	5,010,000	2,068,300	9,778,600	
1945	7,025,000	700,000	4,320,000	5,020,000	2,298,400	12,077,000	
1946	7,208,000	710,000	4,320,000	5,030,000	2,540,300	14,617,300	
1947	7,406,000	720,000	4,320,000	5,040,000	2,804,500	2,421,800	15,000,000
1948	8,018,000	730,000	3,420,000	4,150,000	3,940,700	6,362,500	
1949	8,230,000	740,000	3,420,000	4,160,000	4,260,900	10,623,400	
1950	8,459,000	750,000	3,420,000	4,170,000	4,607,700	5,231,100	10,000,000
1951	8,685,000	760,000	2,820,000	3,580,000	5,261,900	10,493,000	
1952	8,917,000	770,000	2,820,000	3,590,000	5,641,800	6,134,800	10,000,000
1953	9,167,000	780,000	2,220,000	3,000,000	6,351,000	2,485,800	10,000,000
1954	9,413,000	790,000	1,620,000	2,410,000	7,077,600	1,563,400	8,000,000
1955	9,667,000	800,000	1,140,000	1,940,000	7,773,900	1,337,300	8,000,000
1956	9,928,000	810,000	660,000	1,470,000	8,498,100	1,835,400	8,000,000
1957	10,198,000	820,000	180,000	1,000,000	9,253,100	8,088,500	3,000,000
1958 (4 mo)	3,492,000	277,000	0,000 Paid off Jan. 1. Operate 4 months to build up reserve.	277,000	3,295,900	11,384,400	
						Reserve $ 11,384,400	$ 72,000,000

Table No. 47

Tube Line

Based on Diversion of 80% of Total Vehicular Traffic to Tubes. 85% Vehicular Traffic Diverted to Tubes after First 10 Years.
Cost of Project $87,000,000 - Reserve Required for Operating Deficit First Year $9,000,000
Total $96,000,000 Bond Issue Retired in 34 Years Leaving $22,235,400 Reserve Sufficient to Maintain Tube for About 15 years

GROSS AND NET INCOME AND AMORTIZATION USING PRESENT TOLL RATES

YEAR	GROSS INCOME	YEARLY OPERATION	BOND INTEREST	TOTAL YEARLY COST	NET INCOME	RESERVE	BOND RETIREMENT
						$ 9,000,000	
1938	$ 5,754,000	$ 2,100,000	$ 5,760,000	$ 7,860,000	$ 1,836,000*	$ 7,164,000	$
1939	6,105,000	2,100,000	5,760,000	7,860,000	1,540,100*	5,623,900	
1940	6,509,000	2,120,000	5,760,000	7,880,000	1,202,300*	4,421,600	
1941	6,688,000	2,120,000	5,760,000	7,880,000	1,059,400*	3,362,200	
1942	6,888,000	2,140,000	5,760,000	7,900,000	911,100*	2,451,100	
1943	7,095,000	2,160,000	5,760,000	7,920,000	751,500*	1,699,600	
1944	7,308,000	2,180,000	5,760,000	7,940,000	581,000*	1,118,600	
1945	7,527,000	2,200,000	5,760,000	7,960,000	399,400*	719,200	
1946	7,753,000	2,220,000	5,760,000	7,980,000	205,400*	513,800	
1947	8,485,000	2,240,000	5,760,000	8,000,000	500,400	1,014,200	
1948	8,739,000	2,260,000	5,760,000	8,020,000	749,400	1,763,600	
1949	9,001,000	2,280,000	5,760,000	8,040,000	1,013,900	2,777,500	
1950	9,271,000	2,300,000	5,760,000	8,060,000	1,294,300	4,071,800	
1951	9,549,000	2,320,000	5,760,000	8,080,000	1,591,200	5,663,000	
1952	9,835,000	2,340,000	5,760,000	8,100,000	1,904,900	7,567,900	
1953	10,131,000	2,360,000	5,760,000	8,120,000	2,238,000	9,805,900	
1954	10,435,000	2,380,000	5,760,000	8,140,000	2,589,200	12,395,100	
1955	10,748,000	2,400,000	5,760,000	8,160,000	2,959,900	15,355,000	
1956	11,070,000	2,410,000	5,760,000	8,170,000	3,360,700	18,715,700	
1957	11,402,000	2,420,000	5,760,000	8,180,000	3,783,500	22,499,200	
1958	11,745,000	2,430,000	5,760,000	8,190,000	4,230,000	6,729,200	20,000,000
1959	11,750,000	2,440,000	4,560,000	7,000,000	4,951,900	1,681,100	10,000,000
1960	11,750,000	2,440,000	3,960,000	6,400,000	5,400,400	7,081,500	
1961	11,750,000	2,440,000	3,960,000	6,400,000	5,562,400	2,643,900	10,000,000
1962	11,750,000	2,440,000	3,360,000	5,800,000	6,029,300	8,673,200	
1963	11,750,000	2,440,000	3,360,000	5,800,000	6,210,200	4,883,400	10,000,000
1964	11,750,000	2,440,000	2,760,000	5,200,000	6,696,500	11,579,900	
1965	11,750,000	2,440,000	2,760,000	5,200,000	6,897,400	8,477,300	10,000,000
1966	11,750,000	2,440,000	2,160,000	4,600,000	7,404,300	15,881,600	
1967	11,750,000	2,440,000	2,160,000	4,600,000	7,626,400	13,508,000	10,000,000
1968	11,750,000	2,440,000	1,560,000	4,000,000	8,155,200	21,663,200	
1969	11,750,000	2,440,000	1,560,000	4,000,000	8,399,900	20,063,100	10,000,000
1970	11,750,000	2,440,000	960,000	3,400,000	8,951,900	29,015,000	
1971	11,750,000	2,440,000	960,000	3,400,000	9,220,400	22,235,400	16,000,000

Table No. 48

Location No. 5

Based on a Diversion of 40% of Total Transbay Traffic to Bridge. No Railroad Traffic Included.
$30,000,000 Bonds Retired in 17 Years Leaving $8,879,100

GROSS AND NET INCOME AND AMORTIZATION USING PRESENT TOLL RATES

YEAR	GROSS INCOME	YEARLY OPERATION	BOND INTEREST	TOTAL YEARLY COST	NET INCOME	RESERVE	BOND RETIREMENT
1938	$ 2,877,000	$ 370,000	$ 1,800,000	$ 2,170,000	$ 707,000	$ 707,000	$
1939	3,052,000	375,000	1,800,000	2,175,000	898,200	1,605,200	
1940	3,254,000	380,000	1,800,000	2,180,000	1,122,200	2,727,400	
1941	3,344,000	385,000	1,800,000	2,185,000	1,240,800	3,968,200	
1942	3,444,000	390,000	1,800,000	2,190,000	1,373,000	5,341,200	
1943	3,547,000	395,000	1,800,000	2,195,000	1,512,200	6,853,500	
1944	3,654,000	400,000	1,800,000	2,200,000	1,659,600	8,513,100	
1945	3,764,000	405,000	1,800,000	2,205,000	1,814,400	10,327,500	
1946	3,877,000	410,000	1,800,000	2,210,000	1,976,800	12,304,300	
1947	3,993,000	415,000	1,800,000	2,215,000	2,147,100	4,451,400	10,000,000
1948	4,113,000	420,000	1,200,000	1,620,000	2,626,500	7,078,000	
1949	4,236,000	425,000	1,200,000	1,625,000	2,823,300	9,901,300	
1950	4,363,000	430,000	1,200,000	1,630,000	3,030,000	2,931,300	10,000,000
1951	4,494,000	435,000	600,000	1,035,000	3,546,900	6,478,300	
1952	4,628,000	440,000	600,000	1,040,000	3,782,300	10,260,600	
1953	4,767,000	445,000	600,000	1,045,000	4,029,800	4,290,400	10,000,000
1954	4,910,000	450,000	0,000	450,000	4,688,700	8,879,100	
					Reserve	$ 8,879,100	$ 30,000,000

3. General economic considerations.

(a) *General Traffic Utility.*

In the economic study and design of structures on the various lines an attempt has been made to make the traffic utility of the structures as nearly equal as their geographic positions would permit. The greatest traffic utility is attained by the structure which transports the maximum traffic between traffic centers with the least relative cost and congestion. The principal factors in such a consideration are, cost of construction, cost of operation and effective distribution of traffic in San Francisco and Oakland. The first two considerations are represented by the estimated costs of construction and operation.

The matter of effective traffic distribution is determined generally by the answer to the question: Which site offers the quickest and most convenient delivery of travel from one traffic center to the other? The position of automobile and commuter traffic centers is shown on Plate No. 54.

(b) *Locations Nos 1 and 4.*

A careful study of Locations Nos 1 and 4 leads to the conclusion that very little choice, so far as transbay traffic distribution is concerned, exists between the two general lines. Both originate in Oakland at points practically the same distance from the gravity center of automobile and commuter traffic. Both terminate at relatively the same point in San Francisco. Traffic is taken and discharged in San Francisco south of Market street in a district where streets are wide and property of relatively low value. It is more or less self evident that the growth of the city, and consequently its traffic, will be southward. The traffic centers are at present just a short distance north of Market street. The tendency of traffic center movement in a north and south direction is, therefore, toward the bridgehead rather than away from it. Such a condition is considered desirable.

The discharge of passenger automobiles is carried well up toward the traffic center at Market and Van Ness and is, so far as possible, relieved of traveling over the busy streets between Fifth street and the bay. Truck traffic is discharged via a highway loop to the Embarcadero and water front streets where it, for a large part, originates and discharges. Traffic desiring to go to the large district south of Market street and to the Peninsula highways may do so over wide streets and with minimum congestion.

Commuters are discharged at loop stations close to Market street and only a short distance south of the commuter traffic center. The plan shown contemplates discharging main line train passengers at the First street loop station. As an alternate arrangement a passenger terminal can be established on Rincon Hill, just off the bridge.

The interurban train loop is placed on relatively unimportant streets with a minimum of property damage, yet it is close to the desired point of distribution.

Location No. 3 originates at the same point in Oakland as does Location No. 4 and, in this respect, is therefore equal in traffic utility to Locations 1 and 4. Its San Francisco terminal is, however, a considerable distance north of Market street in a district where the streets are narrow and on steep grades. Property values are also higher. The tendency of the centers of traffic is to move away from the point of

discharge in Location No. 3 rather than toward it, as in Locations Nos. 1 and 4. Compared with Locations Nos. 1 and 4, automobile traffic is discharged at a greater distance from the gravity center. To reach this center they must traverse steeper grades over narrower streets, or pass through the busy streets of San Francisco's business center. Traffic destined to the large district south of Market street and to the Peninsula highways must also traverse the busier parts of the city. Traffic going to the northwestern part of the city is discharged somewhat nearer its destination but, from the point of view of discharge, it does not have a much superior exit.

(c) *Location No. 3.*

An effective interurban loop is developed for Location No. 3, but it is much more expensive than the loop for Locations Nos. 1 and 4 and does not deliver the commuter as close to the commuter center. Distribution from Location No. 3 in San Francisco does not provide for a truck ramp to the Embarcadero. In this respect it is, therefore, not comparable to Locations Nos 1 and 4. Such a loop can be developed, but the grades would be greater than 3½ per cent and the ramp would add at least $1,500,000 to the total cost.

(d) *Location No. 5.*

Location No. 5 is not comparable with Locations Nos. 1, 3 and 4 in traffic utility because it does not carry interurban trains. The distance traveled between traffic centers is approximately 5.3 miles farther by Location No. 5 than any of the other locations. Such a difference in distance would probably make it prohibitive for trucks to use this route in preference to ferries. The San Francisco connection is via the Bay Shore Highway. Traffic from the bridge to San Francisco would greatly increase congestion on this important highway.

It is believed that many years will elapse before traffic centers move far enough south to justify Location No. 5 as a major bay crossing. When such a time does arrive, the population of the bay area will have increased to such proportions that a bridge on any of the northern locations will be overloaded. A bridge at Hunter Point does not meet the traffic needs of the bay cities at this time. It can only be considered as a location for the distant future expansion of bridge facilities when a centrally located crossing becomes overcrowded.

(e) *Tube Line.*

The tube line as designed can not be compared with Locations Nos. 1, 3 and 4 in traffic utility, because it carries only vehicular traffic. It may, however, be compared with the single deck structure on Location No. 4. The tube line offers the most direct connection between traffic centers and at the same time makes an excellent distribution of vehicular traffic possible, both in San Francisco and Oakland.

4. Relative studies as to the effects on navigation.

(a) *General.*

Referring to Traffic Survey, Section I-B, a survey of shipping with reference to its dock destination is shown on Plate No. 36. A summation of results is as follows:

During the yearly period a total of 22,633 vessels with a net tonnage

of 17,318,580 tons and a cargo tonnage of 7,403,531 tons passed Location No. 3 to dock in San Francisco.

A total of 9887 vessels with a net tonnage of 11,954,563 tons and a cargo tonnage of 5,139,146 tons passed Location No. 4 to dock in San Francisco.

A total of 8409 vessels with a net tonnage of 8,892,169 tons and a cargo tonnage of 3,699,776 tons passed Location No. 1-A.

A total of 8117 vessels with a net tonnage of 7,678,302 tons and a cargo tonnage of 3,337,423 tons passed Location No. 1.

In addition to the above figures all the shipping to Oakland passed Locations Nos. 3 and 4. Study of these figures leads to the conclusion that Location No. 4 may be considered of less hindrance to navigation than Location No. 3.

(b) *Location No. 1.*

Location No. 1 with respect to commercial shipping may in the same light be considered of less hindrance than either Location No. 3 or No. 4. As docking facilities in San Francisco must develop toward the south, rather than north, this relative advantage of Location No. 1 will become smaller and smaller. Location No. 1 has an added disadvantage in that it crosses the naval anchorage. In this respect it must be considered a much greater hazard to naval maneuvers than are Locations Nos. 3 or 4.

(c) *Comparison of Locations Nos. 3 and 4—Ferry Traffic.*

The effect of Locations Nos. 3 and 4 upon ferry traffic is as follows:

A total of 120 ferryboats pass Location No. 3 daily. They are:

Ferry Building to Sausalito	66
Ferry Building to Richmond	42
Ferry Building to Vallejo	12

These ferries will continue to operate after the bridge is built.

A total of 283 passenger ferry trips, 247 automobile ferry trips and 48 freight ferry trips pass Location No. 4 daily. A bridge carrying interurban passengers on Location No. 4 will eliminate all the passenger and automobile ferries crossing Location No. 4, leaving only the freight ferries.

During the period of construction of a bridge on Location No. 4 it may be necessary to construct a temporary ferry terminal on the west side of Goat Island connected to Oakland by the bridge east of Goat Island and roads and tracks on the island. Such a terminal would be just north of the bridge on the island and would be required for a period of 1½ or 2 years. Piers 3 and 4 of the main channel structure would be constructed last. The period of operation of the temporary Goat Island terminal would start with the beginning of construction of these piers and continue until the completion of the bridge. The cost of such a terminal is estimated at $1,250,000. This cost has not been included in the estimate for Location No. 4 because of its doubtful necessity. Upon the completion of a bridge on Location No. 4 all ferries passing this location except as noted above, will be eliminated.

It is thus shown that upon completion of a bridge there will be a total of 120 ferry trips past Location No. 3, and 48 ferry trips past Location No. 4. In this respect Location No. 4 is superior to Location No. 3.

(d) *Tube Line.*

The economic effect of the tube line on water borne traffic is probably less than any of the bridge structures. It is, however, necessary to erect four large ventilating buildings in the bay and these must be protected by still larger fender structures. Only three major piers are necessary for the bridge structures on Locations Nos. 3 and 4. The ventilating buildings are approximately twice as far apart as the piers, yet they are in main ship channels and must be considered nearly as great a hazard to navigation as are the bridge piers. The danger attending the collision of a ship with one of these ventilating buildings to traffic in the tube would be greater than that attending the collision of a ship with a bridge pier.

5. Relative comparisons as to the effect of various lines on property.

(a) *Location No. 1.*

A study of effect on property in the city of San Francisco indicates that the construction of the distribution system as shown will not involve property damage greater than could be normally expected in a project of this magnitude, the property affected being comparatively cheap and not highly developed.

On the Alameda side, however, it will be necessary to render the Alameda Airport inoperative unless the most expensive structure is built; *i. e.,* Location No. 1-A. It would be much less expensive to build a structure on Location No. 1-C and move the airport. A high structure in the vicinity of airports is to be considered more or less a hazard to airplanes in foggy weather. Crossing the highly developed freight yards of the Southern Pacific Railroad in Oakland will involve more or less damage.

(b) *Location No. 3.*

The property damage involved in constructing the distribution system for highway traffic on Location No. 3 is not unusual for a project of this magnitude. The distribution system for interurban traffic, however, involves the traversing of highly developed streets by elevated tracks and will no doubt be expensive.

Property necessary on the Oakland side is on the Key Route mole and the undeveloped flats adjacent. The line is north of all proposed harbor developments in Oakland and in this respect causes no damage to port facilities.

There are no airports in the vicinity of either terminal of Location No. 3. The high structure of the bridge is adjacent to both sides of Goat Island. Planes flying in foggy weather must hold their altitude to pass over Goat Island for which reason the hazard of the high towers of the bridge to airplanes is greatly reduced.

(c) *Location No. 4.*

The San Francisco traffic distribution system of Location No. 4 is practically identical with that for Location No. 1. As stated under Location No. 1 the property costs involved are not more than would be expected for a project of such magnitude. The property required is relatively cheap and poorly developed. With the exception of two and one-half blocks on First street and one block on Sixth street, the streets traversed are not highly developed. The major part of the

interurban loop traverses narrow streets, yet they are located close to the center of distribution.

The Oakland terminal of Location No. 4 is identical with the Oakland terminal of Location No. 3 and involves a minimum of damage to property and to Oakland harbor development.

No airports are near either terminal and the existence of Goat Island requires that all planes maintain altitude in this vicinity.

Location No. 4 traverses the cable area of the bay. It will be necessary to locate carefully all such cables and if necessary move them off the sites of piers. An amount sufficient for that purpose is included in the construction cost of the bridge. It is assumed that these cables will eventually be carried on the bridge.

Both Locations Nos. 3 and 4 and the proposed bridge structures are so arranged and designed as to cause the least possible damage to property on Goat Island. Steel viaduct spans, rather than fills, are placed over the various parade grounds and major buildings located on the line of the bridge. Road connections to Goat Island from the bridge will be provided if the Navy Department so desires and in this way Goat Island will become more valuable due to direct mainland connections.

(d) *Tube Line.*

The property damage for the tube line is reduced to a minimum. A large part of the distribution system in San Francisco is through subways. Short sections of open cut will be necessary in the transition from subway to street grade. Such sections will, in most cases, be only 24 feet wide and occupy the center of streets with surface traffic lanes remaining on each side.

The interference with traffic during the period of construction will, however, be much greater than for any of the bridge proposals as it will be necessary to excavate streets to place the subway sections. A more or less serious interference with traffic on the Embarcadero will be experienced during the period of constructing the deep tunnel section required.

(e) *Location No. 5.*

No damage to property is apparent in the construction and operation of a bridge on Location No. 5 other than the normal rights of way required in bridge and highway construction.

6. Summation of construction costs, operation, and bond retirement.

Table No. 49 is a general summation of construction estimates, operation costs, bond retirements and reserves for maintenance after tolls are removed. This table shows:

First: Construction cost.

Second: Estimated property requirements.

Third: Initial annual cost of operation.

Fourth: Toll rates necessary to accomplish the respective bond redemption and reserve requirements.

Fifth: Percentage of total transbay traffic which it is estimated will be diverted to the bridge.

Sixth: Number of years required after the opening of the bridge to retire the bonds and establish a reserve for maintenance.

Seventh: Reserve accumulated in each case to be used for maintenance after the bonds are redeemed.

Table No. 49

SUMMARY - CONSTRUCTION COSTS AND BOND RETIREMENT

For Proposed Crossings Shown on Plates 7, 34, 23 & 28

LINE NO.	BRIDGE & APPROACH STRUCTURE	PROPERTY	INITIAL ANNUAL COST OF MAINT. AND OPERATION	TOLL RATES	INITIAL % OF TOTAL TRAFFIC DIVERTED	YEARS REQUIRED TO REDEEM BONDS	RESERVE FOR MAINTENANCE AFTER REDEMPTION	REMARKS
1	$ 101,500,000	$ 4,000,000	$		Not Computed		$	Highway & Inter-urban
1-A	112,500,000	3,750,000			" "			" "
1-B	101,500,000	4,250,000			" "			" "
1-C	91,000,000	4,000,000	730,000	Present Rate	80%	22	11,000,000	" "
3	75,500,000	3,750,000	600,000	Present Rate	80%	17	13,000,000	" "
4	68,600,000	3,400,000	630,000	Present Rate	80%	16	10,500,000	" "
4	68,600,000	3,400,000	640,000	Autos 50¢ Trucks reduced 10%	80% Plus 5%	18	13,500,000	" "
4	68,600,000	3,400,000	650,000	Autos 40¢ Trucks reduced 20%	80% Plus 10%	20.0	11,500,000	" "
4	49,500,000	2,000,000	600,000		Not Computed			Highway Only
5	29,900,000	100,000	370,000	Present Rate	40%	17	9,000,000	" "
Tube	84,700,000	2,240,000	2,100,000	Present Rate	80%	34¢	22,000,000	" "

¢ $9,000,000 required to cover deficit during first years of operation making total bond issue $96,000,000.

SECTION V

SUMMARY AND RECOMMENDATIONS

1. Summary.

(a) *General.*

This report is a compilation of general and specific data on the characteristics of various lines across San Francisco Bay between San Francisco and the East Bay. The lines covered are numbered 1, 1-A, 1-B and 1-C, 2, 3, 4, 5 and a line designated as the Tube Line. They are graphically described on Plate No. 54.

Briefly stated, the report contains the following data:

(b) *Traffic—Highway and Interurban.*

The present facilities for crossing the bay between San Francisco and the East Bay district consist of automobile, passenger and freight ferries. In 1929 the auto ferries carried a total of 4,490,513 cars and 10,174,028 passengers, showing an annual increase of 8.2 per cent. Passenger ferries carried a total of 35,923,855 passengers, a decrease of slightly less than 3 per cent under 1928. The origin and destination of auto traffic in San Francisco is at the Civic Center. In Oakland it is at the intersection of Moss and Oakland avenues.

The origin and destination of commuter traffic in San Francisco is near Fifth and O'Farrell streets. In Oakland it is near Moss and Oakland avenues. The time necessary and the distance traveled between these centers by the present service and that required over the bridge lines is given in the following table.

TABLE No. 50. SAN FRANCISCO BAY TRAFFIC

Origin to Destination—Weighted Average Travel, Distance and Time

	Interurban passenger		Vehicles	
	Distance, miles	Time [1] minutes	Distance, miles	Time [2] minutes
(a) Present ferry service	11.114	58.204	12.846	69.940
(b) Bridge Location 1, Rincon Hill-Alameda Mole	12.073	47.946	12.253	43.752
(c) Bridge Location 2, Potrero Hill-Alameda Mole	14.131	53.040	14.962	51.042
(d) Bridge Location 3, Telegraph Hill-Goat Island	13.334	53.448	13.819	44.418
(e) Bridge Location 4, Rincon Hill-Goat Island	12.457	47.910	13.546	43.206
(f) Bridge Location 5, Hunter Point-Alameda	17.742	62.238	18.416	59.388

[1] Does not include waiting time for trains or boats at terminals.
[2] Waiting time at ferries included.

The traffic centers are slowly moving southward. (Section I-A.)

Growth of automobile traffic may be expected to steadily increase at the rate of 5 per cent to 6 per cent for the next eight or ten years and thereafter at approximately the rate of population growth, which is about 3 per cent per annum.

Income is computed on approximately this basis (see Section IV-2). Growth of interurban traffic can not be expected to any great extent.

Probable revenue from tolls which may be expected over a centrally located bay crossing carrying both auto and electric line passengers in 1940 is approximately $7,400,000 per year. It is estimated that this will increase at the rate of 3 per cent per annum.

Water Borne Traffic.

Water borne traffic on San Francisco Bay has been increasing steadily. In 1924 a total of 13,015 vessels entered the Golden Gate. This number has increased steadily to 15,765 in 1929.

Tables Nos. 26 to 33 give complete data.

Passenger ferry boats have slightly decreased in number since 1925. Automobile ferries have materially increased since 1925.

The total movements per hour of ferry boats in 1925 were 30. In 1929 they were 45. With respect to bridge locations the movement of ships and ferries is briefly summarized as follows:

In 1929 22,633 boats of all classes, not including ferries, passed Location No. 3, 9887 passed Location No. 4 and 8409 passed Location No. 1, all to dock in San Francisco.

There are at the present time 120 ferry boats passing Location No. 3 daily. The building of a bridge will not affect these ferries. At the present time 238 passenger ferries, 247 auto ferries and 48 freight ferries pass Location No. 4. All but the freight ferries passing Location No. 4 will be eliminated by the construction of a bridge.

No ferries pass Location No. 1; however, this location crosses the naval anchorage.

The tube line will have less effect upon the movements of vessels and ferries. It does not eliminate the hazard of piers because of the four ventilating buildings necessary in the bay. A tube line would eliminate only the vehicular ferries.

(c) *Borings and Foundation Data.*

Operations. A contract was let to Duncanson-Harrelson of San Francisco for jetting and drilling. Borings were started January 30, 1930, and completed June 26, 1930, at a cost of approximately $32,150. Both jet and core drilling were used. The total number of feet jetted was 7897, and the total core drilled was 837 feet.

Results. A brief summary of findings follows:

The general character of material encountered was mud and varying types of soft to stiff sandy or gravelly clay overlying shale and sandstone. The shale and sandstone beds are evidently of great depth and increase in hardness as depth is gained. The shale and sandstone is generally in alternate layers very similar to rock excavations found around the bay district. This material is considered a satisfactory foundation for heavy bridge piers and capable of sustaining a foundation pressure of from 25 to 30 tons per square foot under combined maximum loading.

On Location No. 1 shale or rock is encountered 4000 feet from the San Francisco shore at an average depth of approximately 185 feet. From there for a distance of 9000 feet to the Alameda shore the depth to shale increases from 230 to 350 feet.

On Location No. 2 the average depth to shale is found to be more than 300 feet.

On Location No. 3 shale is found between San Francisco and Goat Island at an average depth of 223 feet.

On Location No. 4 shale is found between San Francisco and Goat Island at an average depth of 168 feet.

To the east of and adjacent to Goat Island suitable foundations for the heavy piers are found at from 0 to 250 feet.

On Location No. 5 shale was encountered in only one hole at 369 feet. The overlying material is, however, very firm clay with streaks of sand and gravel and is suitable for pile foundations under the lighter structure necessary at this location.

(d) *Design.*

Capacity. A structure capable of carrying the anticipated traffic should have a capacity of six traffic lanes for highway traffic and at least two operative and one passing or emergency tracks for interurban trains. This applies to Locations Nos. 1, 3 and 4.

The tube line, on account of its great cost, is limited to six lanes of highway traffic only.

Horizontal Clearances. Horizontal navigation clearance on Location No. 1 provides for 1600 feet between fenders adjacent to San Francisco and 600 between fenders over 9000 feet toward the Alameda shore. Horizontal clearance on Locations Nos. 3 and 4 provides for 1600 feet between pier fenders for the entire distance between San Francisco and Goat Island and for 650 feet clearance between fenders for one span over deep water east of Goat Island.

Horizontal clearance for Location No. 5 at one span over the channel provides for approximately 1100 feet between fenders.

Vertical Clearances. Vertical clearance above normal high water on Location No. 1 is 165 feet for the two long spans on the San Francisco side and 150 feet for the series of 750-foot spans.

Vertical clearance on Locations Nos. 3 and 4 above normal high water is 214 feet for the two center spans of the structure between San Francisco and Goat Island and 155 feet for the span east of Goat Island.

Vertical clearance for Location No. 5 is 157 feet above normal high water for the channel span.

Grades. Grades for all structures and approaches are held to 3½ per cent maximum for highways and 3 per cent maximum for electric lines. General Description of Structures is given in Section III, pp. 136 to 139, and is not repeated here.

(e) *Estimates.*

Following is a summary in order of costs giving estimates for structures, on locations which directly connect the centers of origin and destination and which provide for both interurban and highway traffic:

	Bridge and approach structures	*Property*	*Total*
Location No. 4	$68,600,000	$3,400,000	$72,000,000
3	75,500,000	3,750,000	79,250,000
1-C	91,000,000	4,000,000	95,000,000
1	101,500,000	4,000,000	105,500,000
1-B	101,500,000	4,250,000	105,750,000
1-A	112,500,000	3,750,000	116,250,000

For structures on the direct line of travel which provide for highway traffic only the estimates are as follows:

	Bridge and approach structures	*Property*	*Total*
Location No. 4	$49,500,000	$2,000,000	$51,500,000
Tube	93,760,000	2,240,000	96,000,000

The cost given for the tube includes $9,000,000 required to cover deficit during first years of operation.

From the above it will be seen that Location No. 4 provides the most economical crossing of the bay for a structure with terminals near the centers of origin and destination.

A bridge on Location No. 3 will be more expensive than Location No. 4 chiefly on account of higher cost of terminals in San Francisco and the greater cost of foundation for the main spans.

The above table shows a difference of $7,250,000 between the estimates for Locations Nos. 3 and 4. For comparative purposes the estimate for Location No. 3 should be raised $922,000 since the estimate for Location No. 4 is based on an elevated connection with the railroad lines at Sixteenth street in Oakland and the estimate for Location No. 3 is based on a ground level connection. (See detail estimates, Tables No. 38 and No. 39—Key Route Mole-Yerba Buena street). This adjustment shows the cost of Location No. 3 to be more than $8,000,000 greater than Location No. 4.

Location No. 1-C, which is the cheapest alternative on Location No. 1, will cost about $23,000,000 more than a similar bridge on location No. 4. The foundations on Location No. 1 are more expensive. The main bridge structure on Location No. 1 is about one and three-quarter miles longer than the main bridge structure on Location No. 4 due to the use of Goat Island and the Key Route Mole on Location No. 4. These two items of more expensive foundations and longer main structure make Location No. 1-C cost $17,000,000 more than Location No. 4. On account of the crossing of the estuary and Southern Pacific Company yards the East Bay connections for Location No. 1-C will cost about $5,400,000 more than the Oakland connections for Location No. 4. It is estimated property costs on Location No. 1-C will exceed property costs on Location No. 4 by $600,000. The above items account for the $23,000,000 excess in cost for Location No. 1-C.

The first cost of tubes providing for six lanes of highway traffic, but no interurban cars, is very nearly the same as for a bridge on Location No. 1-C which provides for both highway and interurban traffic. In other words, the tube line exceeds the cost of a bridge providing for automobiles and interurban on Location No. 4 by more than $20,000,000. A bridge on Location No. 4 to provide facilities equal to the tubes will cost only $51,500,000.

The advantage in first cost which Location No. 4 has over Locations Nos. 1 and 3 permits a minimum toll charge on this location. If the bridge is built on Location No. 4 the tolls on passenger cars can be reduced from sixty cents, the present rate, to forty cents; truck tolls reduced 20 per cent and the bridge paid for in twenty years. To pay for a bridge on Location 1-C in a like period no reduction in present tolls will be possible.

(f) *Terminals.*

San Francisco Terminals. On the San Francisco side only two general locations for terminals need to be considered—in the vicinities of Rincon Hill and Telegraph Hill.

The Rincon Hill location permits the construction of suitable approaches on easy grades, particularly for truck traffic. The adjacent streets are wide and without any steep grades. Vehicular traffic can reach Market street, the Mission district, the Peninsula highways, and the center of vehicle traffic without traversing streets already excessively congested by vehicular and pedestrian traffic. A loop for interurban passenger service can be built, largely along alleyways, which will cause comparatively little interference with existing commercial and property conditions. Passengers can be discharged within a block of Market street, from First street to Sixth street.

At the Telegraph Hill location it is impractical to provide suitable approach grades for truck traffic. (See Section III-5.) The adjacent streets are, for the most part, narrow and there are many excessively steep grades. Vehicular traffic has ready access to the Golden Gate district but otherwise must traverse congested and relatively narrow streets. A loop for interurban service can be built to serve the center of commuter traffic satisfactorily but only by building it along the streets, which will necessitate a great deal of change in existing commercial and property conditions.

Bridge Location No. 3 has its San Francisco terminals on Telegraph Hill. Locations Nos 4, 1, 1-A, 1-B, 1-C and the Tube Line terminate in the vicinity of Rincon Hill.

East Bay Terminals. On the East Bay side, Locations Nos. 3 and 4 terminate in the vicinity of the Key Route Mole, the Tube Line at the Oakland Mole and Nos. 1, 1-A, 1-B, 1-C and 5 at various points in Alameda. All routes connect with the existing interurban lines and vehicular traffic is carried in each case to a connection with the streets of Oakland.

A terminal in the vicinity of the Key Route Mole provides direct connections for vehicular traffic with San Pablo avenue and the north via Yerba Buena avenue and with the business district of Oakland via Twenty-second street. The center of traffic is reached without going through the more congested streets of Oakland. To reach areas to the south of Oakland at the present time, traffic must pass through or close to the business district. This condition will be alleviated as the street planning program is carried out. No difficult or expensive construction is necessary to connect with the existing interurban lines. This location neither interferes with the present or proposed development of Oakland's outer harbor nor does it materially affect existing commercial property or conditions.

The terminal for the Tube Line on the Oakland Mole would not change the existing vehicular traffic connections. No provision for interurban train traffic through the tube has been considered.

Terminals in Alameda all require expensive structures across the estuary to bring both vehicular and interurban traffic into the center of Oakland. To reach the center of traffic, railroad yards must also be crossed and the Alameda Airport will be interfered with seriously

if not made entirely useless. Direct connection with East Fourteenth street and the lower East Bay would be provided without traversing congested areas.

2. Conclusions and recommendations.

A study of the data assembled in this report leads to the following conclusions:

First: The construction of a bay crossing to transport existing and future transbay traffic between San Francisco and East Bay cities is very necessary to the development of the bay and is entirely feasible from economic and construction viewpoints.

Second: The present and future traffic needs for many years to come require that such a crossing be located on a relatively direct line between the centers of automobile and commuter traffic and that it carry both automobile and interurban traffic.

Third: That the centers of automobile and commuter traffic, though moving slowly southward, will remain approximately in their present positions until such time as the proposed crossing is carrying its full capacity.

Fourth: That in consideration of conclusions 2 and 3, the proper locations to be considered at present are Location No. 1 (Rincon Hill-Alameda), Location No. 3 (Telegraph Hill-Key Route Mole), Location No. 4 (Rincon Hill-Key Route Mole), and the Tube Line.

Location No. 5 should be considered only for future bridge expansion when a crossing centrally located has become congested.

Fifth: That piers for all the heavy spans should be founded on the best possible material available. This is shale and sandstone.

Sixth: That the best possible traffic distribution centers for both highway and interurban traffic are necessary both in San Francisco and Oakland and should be built complete as part of the bridge project.

Seventh: That a structure capable of carrying the anticipated traffic must provide for six lanes of vehicular traffic and two operative interurban tracks with a third passing or emergency track.

Eighth: That the most economic structure for the traffic requirements is a double deck structure with six lanes of vehicular traffic on the upper deck and the required tracks on the lower deck.

Ninth: That the bridge must offer a minimum of interference to both naval and commercial navigation.

Tenth: A further conclusion is that a bridge constructed on Location No. 4, from Rincon Hill, via Goat Island, to the Key Route Mole, will best meet these requirements.

Its selection is recommended for the following reasons:

(a) No other location offers a more direct connection between traffic centers.

(b) Location No. 4 is the only location on which shale or rock foundations can be obtained for all heavy piers within practical depths.

(c) The cost of a double deck structure on Location No. 4 is $7,250,000 less than on Location No. 3 and $23,000,000 less than the cheapest structure on Location No. 1, *i. e.,* Location No. 1-C.

(d) Location No. 4 connects the most desirable traffic distribution centers in San Francisco and Oakland.

(e) Location No. 4 is superior to Location No. 3 in its effect on navigation and Location No. 1 shows no advantage in this respect when naval interests are considered.

(f) On Location No. 4 the present rate of ferry tolls can be materially reduced and the bridge paid for in less than twenty years.

Recomendations.

After careful study of all considerations involved, we recommend:

That Location No. 4, from the Rincon Hill district in San Francisco, via Goat Island, to Oakland over the Key Route Mole be adopted.

That a double deck structure, with six traffic lanes on the upper deck and interurban tracks on the lower deck, with proper terminal facilities be built.

That main channel spans 1700 feet long be used, with 220 feet vertical clearance above low water and approximately 1600 feet horizontal clearance between pier fenders.

APPENDIX

BORING DATA

SAN FRANCISCO BAY BORINGS

BORING No. 1

Position—
N. 79° 08′ E., 4800 feet from Pier 34.
Schmidt Bldg. Clock Tower
32° 58′
Ferry Bldg. Tower
82° 37′
Goat Island Lighthouse

Depth of Water—64.0 feet
Depth of Boring—208 feet
Chronology—

Started for Boring No. 1	Noon January 30, 1930
Arrived at Boring No. 1	2.00 p.m. January 30
Started to put out anchors	2.00 p.m. January 30
All anchors out	9.00 a.m. January 31
Started jetting	10.00 a.m. February 3
Finished jetting	11.00 a.m. February 4
Left Boring No. 1	9.00 a.m. February 5

Total jetting time, 9 hours
Total time at point, 29 hours

Log—
Depth of water 64 feet.
–64 to –88 easy going, 40 lbs. gage pressure.
–88 to –116 easy going, 50 lbs. gage pressure.
Pressure jumped to 100 lbs. at elevation –135.
Obtained Sample No. 1 at elevation –64. Sample No. 2 at elevation –88. Sample No. 3 at elevation –135.
Pressure—75 lbs. to elevation –155. Sample No. 4 at elevation –155. Sample No. 5 at elevation –208.
Hard going at elevation –172, gage pressure 300 lbs. Easy going to elevation –197 and to elevation –216. From elevation –216 to elevation –226 the jet worked through a hard stratum; then alternately hard and soft strata from elevation –227 to elevation –232.
Stopped at elevation –238, could not get sample pipe to bottom so decided to pull up jet. Found jet pipe broken off at elevation –208.

BORING No. 2

Position—

N. 79° 08′ E., 6783 feet from Pier 34, then 33 feet right.
Schmidt Bldg. Clock Tower
26° 22′
Ferry Bldg. Tower
74° 12′
Goat Island Lighthouse

Depth of Water—61 feet
Depth of Boring—293 feet
Chronology—

Began boring	9.20	February 6
Finished boring	10.00	February 7
Working hours, 12⅔ actual boring time		
Moved from Boring No. 1	9.00 a.m.	February 5
Arrived at Boring No. 2	11.40 a.m.	February 5
Moved from Boring No. 2	4.00 p.m.	February 7

Depths from Mean Lower Low water

Log—

Took Sample No. 1 of mud at bottom of Bay, elevation –61 and started jetting at 9.20 a.m. February 6, 1930. Jet went down easy under 45 lbs. water pressure to elevation –110 where pressure suddenly jumped to 150 lbs. Attempted to get sample; unsuccessful.

Easy going at 75 lbs. to elevation –153. Could obtain no sample at elevation –153. Fairly compact material and hard going from elevation –153 to eleva- –194, 75 lbs. to 200 lbs. pressure.

Jet went slowly from elevation –170 to elevation –194. Metallic click in jet pipe in this stretch. Water hammer probably caused by compact material. Water pressure 200 lbs.

Obtained Sample No. 2 at elevation –194. Went down to elevation –215 at 75 lbs. pressure. Struck an apparently hard stratum at elevation –223±, jet became stuck and was extricated after 10 minutes work.

Elevation –215 to elevation –235 150 lbs. water pressure.

Elevation –235 to elevation –257 250 lbs. water pressure.

Sample No. 3 at elevation –257.

Elevation –247 to elevation –257 went down at rate of 1 foot in 5 minutes, then fairly easily to elevation –262.

Went down hard from elevation –262 to elevation –265, then easy to elevation –282. Gage pressure, 250 lbs. from elevation –257 to elevation –282. Tried unsuccessfully to get sample.

Went easy to elevation –290, then very hard under 250 lbs. to elevation –293 at 9.55 a.m.

Could get no sample. Bottom seemed hard. Tried jetting again but jet would go no farther.

Brought up minute particle of shattered rock or gravel from elevation –293.

BORING No. 3

Position—

N. 79° 08′ E., 7783 feet from Pier 34, then 58 feet left.
Ferry Bldg. Tower
69° 14′
Goat Island Lighthouse
72° 31′
Western Pacific Mole—Center Line Gable

Depth of Water—56 feet
Depth of Boring—301 feet
Chronology—

Started for Boring No. 3 from Pier 36	7.30 a.m.	February 10
Started jetting	2.00 p.m.	February 10
Finished jetting	3.30 p.m.	February 11
Started for Boring No. 4	11.30 a.m.	February 12

Total jetting time, 9½ hours
Total time at Boring No. 3, 19½ hours

Log—

Sample No. 1, elevation –56	Surface mud and shells, blue clay, gradually increasing in density to elevation –165.
Sample No. 2, elevation –170	Water washed gravel and clay. This stratum of gravel, as near as could be judged by the behavior of jet pipe and pump, extends from about elevation –165 to elevation –175. Gage pressure jumped from 50 lbs. to 150 lbs. at elevation –175 and increased to 250 lbs. at elevation –180.
Sample No. 3, elevation –180	Blue clay. Went down easily to elevation –215 where gage again went up to 250 lbs. Hard going to elevation –251.
Sample No. 4, elevation –251	Compact yellow sand and clay. Jetting shut down from 11.30 a.m. to 12.30 p.m. to go over hose connections and eat lunch. Jet went down slowly under 250 lbs. to elevation –289, then jet only had to be dropped three times to run down to elevation –301, and was still going fast when stopped. Would have had to put on more pipe to go farther.

Gage pressure 150 lbs. from elevation –289 to elevation –301. Attempted to get sample at elevation –301 but was unable to do so. Once a small quantity of yellow sand and clay came up sticking to sample pipe, similar to Sample No. 4, but with more and coarser sand.

BORING No. 4

Position—

N. 79° 08′ E., 15,050 feet from Pier 34.
South Power Tower
62° 06′
Alameda Mole—Center Line Outer Gable
20° 44′
High Tank, S. P. Oakland Mole

Depth of Water—20 feet
Depth of Boring—300 feet
Chronology—

Left Boring No. 3	11.30 a.m. February 12
Arrived at Boring No. 4	1.00 p.m. February 12
Anchors in place	2.00 p.m. February 12
Started jetting	8.00 a.m. February 13
Finished jetting	11.50 a.m. February 13
Started to pull up anchors	1.00 p.m. February 13
Left Boring No. 4	2.00 p.m. February 13

Total jetting time, 3 hours 50 minutes
Total time at Boring No. 4, 10 hours

Log—

Sample No. 1, elevation –20	Surface—almost pure clay (blue). Jet went down easily under 40–50 lbs. pressure to elevation –89. Elevation –89 to elevation –97, stiff clay. Pressure 150 lbs.
Sample No. 2, elevation –97	Blue clay with some fine sand. From action of jet and slight loss of pressure on gage, it seems like there was a layer of gravel from elevation –129± to elevation –136±.
Sample No. 3, elevation –140	Same as No. 1 and No. 2.
Sample No. 4, elevation –171	Blue clay.
Sample No. 5, elevation –211	Blue clay.
Sample No. 6, elevation –252	Blue clay with considerable sand.

Apparently thin gravel stratum at elevation –265±. Went very hard about 1 inch per jounce from elevation –265± to elevation –280±, at 300 lbs. to 350 lbs. pressure.
Stopped jetting at 11.50 a.m.
Sample No. 7, elevation –300 feet same as No. 6

BORING No. 5

Position—
N. 79° 08′ E., 2617 feet from Pier 34.
Schmidt Bldg. Clock Tower
44° 11′
Ferry Bldg. Tower
83° 54½′
Goat Island Lighthouse

Depth of Water—45.2 feet
Depth of Boring—50.4 feet
Chronology—

Left Pier 16	7.00 a.m.	February 14
Arrived at Boring No. 5	8.00 a.m.	February 14
Anchors in place	9.30 a.m.	February 14
Started jetting	12.45 p.m.	February 14
Finished jetting	1.30 p.m.	February 14
Started to pull up anchors	10.20 a.m.	February 17
Left Boring No. 5	10.20 a.m.	February 17

Total jetting time, 45 minutes
Total time at point, 10 hours 20 minutes
Log—
Jet went very hard from the start. Could get but a small sample at surface. 250 lbs. gage pressure.

Sample No. 1, elevation –45.2	Surface mud and some gravel.
Sample No. 2, elevation –50.5	Yellow sand and clay.
Sample No. 3, elevation –50.5	Sandstone.

BORING No. 6

Position—
N. 79° 08′ E., 2450 feet from Pier 34.
Schmidt Bldg. Tower
45° 30′
Ferry Bldg. Tower
83° 39′
Goat Island Lighthouse

Depth of Water—48 feet
Depth of Boring—49 feet
Chronology—

Left Boring No. 5	10.20 a.m.	February 17
Arrived Boring No. 6	10.35 a.m.	February 17
Started drilling	10.45 a.m.	February 17
Finished drilling	11.30 a.m.	February 17
Left Boring No. 6	11.45 a.m.	February 17

Drilling time, 45 minutes
Total time at point, 1 hour 25 minutes
Log—
Did not move anchors. Shifted by hauling in and paying out on anchor lines, leaving anchors in place for Boring No. 5.
Hard Material. Could only penetrate about 1 foot. Samples No. 1 and No. 2, rock fragments obtained by chisel bit and sample pipe—sandstone.

BORING No. 7

Position—
N. 79° 08′ E., 2600 feet from Pier 34, then 183 feet right.
Schmidt Bldg. Tower
43° 41′
Ferry Bldg. Tower
82° 00′
Goat Island Lighthouse

Depth of Water—36.2 feet
Depth of Boring—44.5 feet
Chronology—

Left Boring No. 6	11.45 a.m.	February 17
Arrived Boring No. 7	1.15 p.m.	February 17
Started drilling	1.20 p.m.	February 17

Finished drilling 3.10 p.m. February 17
Left Boring No. 7 4.05 p.m. February 17
Boring time, 1 hour 50 minutes
Total time at point, 2 hours 50 minutes
Sample No. 1, elevation –36.2 Surface rock fragments—sandstone.
Hit rock at surface. Obtained 6-inch penetration with Keystone chisel bit and 8 feet 3 inches with water jet to elevation –44.5.
Were obtaining no additional penetration when jet was stopped. Stopped at elevation –44.5.

BORING No. 8

Position—
Boring made through hole in end of Pier 22 on center line of Pier 22, 5 feet west of east end of dock.

Depth of Water—51.6 feet
Depth of Boring—163.5 feet
Chronology—

Left Boring No. 7	4.05 p.m. February 17
Got into position	10.25 a.m. February 18
Started jetting	10.30 a.m. February 18
Finished jetting	2.50 p.m. February 18
Left Boring No. 8	4.30 p.m. February 18

Total jetting time, 3 hours 50 minutes
Total time at point, 6 hours 5 minutes
Sixty feet of 8-inch pipe placed in hole, penetrating to depth of 20 feet in mud below bottom of bay under its own weight. Ran jet pipe through it to elevation –163.5. Removed jet pipe and replaced it with new 3-inch pipe to same elevation. Washed hole clean and left 3-inch pipe in place in readiness for diamond drilling.

Log—
Pipe sank through 20 feet of mud by its own weight, elevation –51.6 to elevation –70.
Went easily under 150 lbs. pressure to elevation -115.

Sample No. 1, elevation –115	Sand and clay. Easy going to elevation –140 where jet struck hard material and acted as it did over Rincon Reef.
Sample No. 2, elevation –155.	Hard compact gravelly clay. Elevation –140 to elevation –150, hard stratum which took about 12 minutes jetting to penetrate. Elevation –163.5 hit very hard material. Jetted steadily for 8 minutes without obtaining any additional penetration.
Sample No. 3, elevation –163.5	Rock fragments broken off by jet. Elevation –155 to elevation –163.5 jet went down very slowly. No trouble to pull jet out of this.

Chronology—

Erected diamond drill rig	7.30 a.m. to 4.00 p.m. May 27, 1930
Started diamond drilling	7.30 a.m. May 28, 1930
Used City water supply	May 27 to June 4, 1930, inclusive. Oil and water barge used to pump water from June 4 to June 6, 1930.

Stopped diamond drilling, released equipment and crew noon June 6, 1930.
Diamond drill dismantled, released crew and equipment during afternoon of June 6, 1930.
Jet crew dismantled tripod, cleaned up and repaired hole in dock, 10.20 a.m. to 2.10 p. m. June 13, 1930.

Sample List—
Samples Nos. 4A and 4B, elevation –163.5 to –167.6. Hard black shale.
Samples Nos. 5A, B and C, elevation –167.6 to –169.1. Hard shale with veinlets of calcite.
Samples Nos. 6A and 6B, elevation –169.1 to –171.5. Hard sandy shale.
Samples Nos. 7A and 7B, elevation –171.5 to –176.6. Hard shale with veinlets of calcite.
Sample No. 8, elevation –181 to –186. Hard shale with veinlets of calcite, a little sandier than above.
Sample No. 9, elevation –186 to –188.7. Same as No. 8.
Sample No. 10, elevation –188.7 to –191. Same as No. 8.

Sample No. 11, elevation –191 to –193.2. Same as No. 8.
Sample No. 12, elevation –193.2 to –198.2. Very hard sandy shale with calcite veinlets.
Sample No. 13, elevation –198.2 to –202.2. Same as sample No. 12.
Sample No. 14, elevation –202.2 to –207.2. Same as above with one small piece of sandstone.

Log—

Elevation –51.6 to –70	Fine silt
Elevation –70 to –140	Soft gray sandy clay
Elevation –140 to –150	Hard compact sandy clay
Elevation –150 to –163.5	Hard compact gravelly clay
Elevation –163.5 to –167.6	Hard shale, many seams
Elevation –167.6 to –169.1	Hard shale with veinlets of calcite
Elevation –169.1 to –171.5	Sandy shale with veinlets of calcite
Elevation –171.5 to –176.6	Hard shale with veinlets of calcite
Elevation –176.6 to –181	Probably soft shale (no core)
Elevation –181 to –186	Shale with veins of calcite interlaid with soft shale which did not core
Elevation –186 to –193.2	Shale with streaks of calcite
Elevation –193.2 to –206.9	Very hard sandy shale with veinlets of calcite
Elevation –206.9 to –207.2	Hard sandstone

BORING No. 9

Position—
N. 79° 08′ E., 1650 feet from Pier 34.
Schmidt Bldg. Tower
51° 35′
Ferry Bldg. Tower
81° 24′
Goat Island Lighthouse

Depth of Water—65 feet
Depth of Boring—110 feet
Chronology—

Left Boring No. 8	9.25 a.m.	February 19
Arrived Boring No. 9	10.15 a.m.	February 19
Anchors in place	12.30 p.m.	February 19
Started jetting	9.15 a.m.	February 20
Finished jetting	10.00 a.m.	February 20
Started to pull anchors	11.35 a.m.	February 20
Left Boring No. 9	12.13 p.m.	February 20

Total jetting time, 45 minutes
Total time at Boring No. 9, 10 hours 28 minutes

Log—

Sample No. 1, elevation –65 Surface material, soft sandy clay.
Jet went down easily under pressure of 50 lbs. to 75 lbs. to elevation –86. Elevation –86 to –106 jet went down hard and pressure increased from 75 lbs. to 300 lbs. and would stall the pumps.
Sample No. 2, elevation –106 Almost pure clay. Forced jet down to absolute refusal at elevation –111.
Sample No. 3, elevation –111 Shattered fragments of rock mixed with blue clay. Stopped at elevation –111 because jet would go no farther.
Note—When sample was being taken at elevation –106, a steady stream of water came up the jet pipe when union was disconnected. After placing 40 feet more of jet pipe, the water still came pouring out of the top which was 65± feet above the water surface of the bay.

BORING No. 10

Position—
N. 42° 24′ E., 7583 feet from Pier 22.
Schmidt Bldg. Clock Tower
18° 55′
Ferry Bldg. Tower
21° 10½′
Telegraph Hill Flag Pole

Depth of Water—51.3 feet
Depth of Boring—87.2 feet
Chronology—

Left Pier 36	7.25 a.m.	February 21
Arrived at Boring No. 10	9.05 a.m.	February 21
Anchors in place	7.47 a.m.	February 21
Started jetting	10.45 a.m.	February 21
Finished jetting	11.40 a.m.	February 21
Started to pull anchors	1.20 p.m.	February 21
Left Boring No. 10	2.00 p.m.	February 21

Total jetting time, 55 minutes
Total time at Boring No. 10, 6 hours 35 minutes
Log—

Sample No. 1, elevation –51.3. Surface muck, soft blue clay and sand. Went down easily under 50 to 100 lbs. pressure to elevation –80±. Here a hard stratum about 2 feet thick was encountered which caused the water gage pressure to jump to 300 lbs. The next 5 feet was hard going; the gage registered 150 lbs. to 250 lbs. At elevation –82± the jet, in being churned, went down about 2½ inches per blow. This gradually slackened to 1 inch per blow at elevation –86±, then gradually slackened until no further penetration could be obtained at elevation –87.2 feet.

Sample No. 2, elevation –87.2. Sandstone fragments.

BORING No. 11

Position—
About 1 foot out from end of Pier 34 on center line.

Depth of Water—26.6 feet
Depth of Boring—223 feet
Chronology—

Started to move barge from south side of Pier 34 around to end	7.40 a.m.	February 25
Arrived in position	9.00 a.m.	February 25
Started jetting	9.55 a.m.	February 25
Finished jetting	1.35 p.m.	February 25
Left location	3.30 p.m.	February 25

Total jetting time, 3 hours 40 minutes
Total time at Boring No. 11, 6 hours 30 minutes
Log—

Sample No. 1, elevation –27	Surface muck, blue clay and sand. Went down easily to elevation –63. Started going down hard at elevation –63. at rate of about 2 inches per blow, as pipe was being churned down to elevation –73. Then went down fairly easily under 150 lbs. to 200 lbs. pressure down to elevation –103.
Sample No. 2, elevation –103	Stiff blue clay. Stiffened slightly and went down 4 inches or 5 inches per blow under 200 lbs. to 300 lbs. pressure to elevation –186 where going became slower.
Sample No. 3, elevation –186	Stiff yellowish gray clay with some fine sand. Went down hard from elevation –186, slowing gradually from 5 inches per blow at elevation –186 to 1 inch per blow at elevation –223.
Sample No. 4, elevation –223	Shattered fragments of rock, broken by jet and mixed with sand and clay. Stopped jetting at elevation –223 as no additional penetration could be obtained.

BORING No. 12

Position—
N. 42° 24′ E., 5967 feet from Pier 22.
Flag Pole, Telegraph Hill
22° 58′
Tower, Ferry Bldg.
23° 20′
Tower, Schmidt Bldg.

Depth of Water—92 feet
Depth of Boring—158.5 feet
Chronology—

Left Pier 34	7.00 a.m. February 26
Arrived at Boring No. 12	8.55 a.m. February 26
Started to put out anchors	8.55 a.m. February 26
Anchors all out and barge in position	10.15 a.m. February 26
Started jetting	11.30 a.m. February 27
Finished jetting	2.15 p.m. February 27
Left Boring No. 12	2.15 p.m. February 28

Total jetting time, 2 hours 15 minutes
Total time at point, 21 hours 30 minutes
Log—

Sample No. 1, elevation –92	Elevation –92, surface muck, blue clay with some fairly coarse sand. Jet pipe went down 10 feet under its own weight, then easily for 20 feet, until it struck stiff material. It went slowly under 250 lbs. pressure for a few feet and then fairly easily to elevation –144.
Sample No. 2, elevation –144	Stiff blue clay. Went down hard, gradually diminishing from 1 inch per blow at elevation –144 to refusal at elevation –158.5. Stopped jetting here as no additional penetration could be obtained.
Sample No. 3, elevation –158.5	Shattered rock fragments in yellowish gray clay.

BORING No. 13

Position—
S. 78° 45′ W., 7917 feet from Key Route fill, then 200 feet left.
Key Route Pier, Center Line Gable
23° 56′
High Tank on Oakland Mole
21° 35½′
Western Pacific Mole, Center Line Gable

Depth of Water—51.3 feet
Depth of Boring—269.5 feet
Chronology—

Left Pier 34	7.00 a.m. March 5
Arrived at Boring No. 13	8.10 a.m. March 5
Started to put out anchors	8.20 a.m. March 5
Anchors all out	9.25 a.m. March 5
Started jetting	10.00 a.m. March 5
Finished jetting	9.15 a.m. March 6
Left Boring No. 13	12.00 noon March 6

Total jetting time, 6 hours 30 minutes
Total time at point, 12 hours
Log—

Sample No. 1, elevation –51.3	Soft surface muck. Jet went down easily to elevation –98. From elevation –82 to –148, went down at the rate of 5 inches per blow by "jouncing" or "churning" the jet up and down with the donkey engine.
Sample No. 2, elevation –108	Stiff blue clay.
Sample No. 3, elevation –148	Stiff bluish-gray clay mixed with broken shells. Went down easily under 250 lbs. pressure and at the rate of 6 inches per blow to elevation –190.
Sample No. 4, elevation –190	Stiff bluish-gray clay. Went down hard at 250 lbs. pressure and about 2 inches per blow to elevation –198, then very easily under about 175 lbs. to 225 lbs. pressure and several feet per blow to elevation –230.
Sample No. 5, elevation –230	Stiff bluish-gray clay with a small amount of gravel. Went down easily to elevation –250± then started to go down hard. Kept going,

but at a decreasing rate, to refusal at elevation –269. Stopped at elevation –269.5 because no additional penetration could be obtained.

BORING No. 14

Position—
S. 78° 45′ W., 3233 feet from Key Route fill, then 67 feet right.
Junction of Trestle with Fill 77° 28′
Western Pacific Mole, Center Line Gable 101° 09′
N. W. Corner, Key Route Pier

Depth of Water—10.2 feet
Depth of Boring—323.5 feet
Chronology—

Left Boring No. 13	12.00 noon	March 6
Arrived at Boring No. 14	12.30 p.m.	March 6
Started to put out anchors	12.30 p.m.	March 6
All anchors out	1.30 p.m.	March 6
Started jetting	3.30 p.m.	March 6
Finished jetting	12.00 noon	March 7
Left Boring No. 14	2.25 p.m.	March 7

Total jetting time, 5 hours
Total time at point, 10 hours 30 minutes
Log—

Sample No. 1, elevation –11	Surface muck, sand, clay and shells. Jet went down 5 feet under its own weight. Struck a hard streak about 1 foot thick at elevation –25±, then very easily to elevation –52.
Sample No. 2, elevation –52	Gray saud. Went easily to elevation –90±.
Sample No. 3, elevation –90±	Dark gray clay and sand.
Sample No. 4, elevation –130	Dark gray clay and sand. Went down easily under 150 lbs. to elevation –175.
Sample No. 5, elevation –175	Stiff yellowish gray clay. Started to go hard and pressure steadily increased to 250 lbs. at elevation –217.
Sample No. 6, elevation –217	Very stiff dark gray clay. Went down fairly hard to elevation –258.
Sample No. 7, elevation –258	Sand and clay. Continued to go hard to elevation –301.
Sample No. 8, elevation –301	Sand and clay. Jet kept going increasingly hard to refusal at elevation –323.5 where jetting was stopped.

BORING No. 15

Position—
At end of Pier 24 on center line.

Depth of Water—60 feet
Depth of Boring—88.5 feet
Chronology—

Left north side Pier 24	7.00 a.m.	March 10
Arrived at Boring No. 15	7.30 a.m.	March 10
Started jetting	9.00 a.m.	March 10
Finished jetting	9.15 a.m.	March 10
Left Boring No. 15	9.50 a.m.	March 10

Total jetting time, 15 minutes
Total time at point, 2 hours 50 minutes
Log—

Sample No. 1, elevation –60	Surface muck, clay and shells. Jet sank immediately to elevation –86 and then took 10 minutes to go to refusal at elevation –88.5 where we stopped as no additional penetration could be obtained.
Sample No. 2, elevation –88.5	Shattered fragments of rock.

BORING No. 16

Position—
S. 78° 45′ W., 8483 feet from Key Route fill, then 342 feet left.
Key Route Pier, Center Line Gable
24° 14′
Oakland Mole, High Tank
21° 17′
Western Pacific Mole, Center Line Gable

Depth of Water—84.7 feet
Depth of Boring—217 feet
Chronology—

Left Boring No. 15	9.50 a.m.	March 10
Arrived at Boring No. 16	10.35 a.m.	March 10
Started to place anchors	10.35 a.m.	March 10
All anchors placed	11.45 a.m.	March 10
Started jetting	2.20 p.m.	March 10
Finished jetting	8.25 a.m.	March 11
Left Boring No. 16	10.05 a.m.	March 11

Total jetting time, 1 hour 30 minutes
Total time at point, 7 hours 5 minutes

Log—

Sample No. 1, elevation –84.7	Sticky clay and sand. Jet went down through stiff material to elevation –130 under 250 lbs. pressure.
Sample No. 2, elevation –130	Stiff clay. Penetrated at the same rate through apparently the same material to elevation –169.
Sample No. 3, elevation –169	Sand, clay and shells. Jet traveled at approximately the same rate to elevation –209.
Sample No. 4, elevation –210	Green sandy clay. Jet went down from elevation –190± to –217 at about 4 inches per jounce under 200 lbs. to 250 lbs. pressure. Came up solid at elevation –217.
Sample No. 5, elevation –217	Shattered fragments of rock broken off by jet nozzle. Stopped jetting at elevation –217 as no further penetration could be obtained.

BORING No. 17

Position—
N. 79° 08′ E., 11,683 feet from Pier 34, then 33 feet right.
South Power Tower
56° 54′
High Tank, S. P. Oakland Mole
35° 55′
Key Route Pier, Center Line Gable

Depth of Water—31.6 feet
Depth of Boring—294 feet
Chronology—

Left Boring No. 16	10.05 a.m.	March 11
Arrived Boring No. 17	12.50 p.m.	March 11
Started to place anchors	12.50 p.m.	March 11
All anchors placed	1.55 p.m.	March 11
Started jetting	3.30 p.m.	March 11
Finished jetting	12.30 p.m.	March 12
Left Boring No. 17	2.40 p.m.	March 12

Total boring time, 5 hours 30 minutes
Total time at point, 11 hours 40 minutes

Log—

Sample No. 1, elevation –31.6	Muck mixed with shells Jet went down easily to elevation –88.
Sample No. 2, elevation –88	Gray clay mixed with some fine sand. Jet went down very easily under 50 lbs. to 100 lbs. pressure to elevation –123.
Sample No. 3, elevation –123	Dark brown clayey material which appears to contain some organic matter. Jet kept going

at about the same rate under 50 lbs. to 100 lbs. pressure to elevation –162.

Sample No. 4, elevation –162 — Sand and fine gravel.* This stratum of gravel was apparently struck at elevation –150± as the jet stuck at this elevation and would not go down again after it was raised preparatory to continuing churning. Pressure up to 350 lbs. was developed and the buck line was used in an effort to force it down. A section of pipe was removed and churning resumed at elevation –150±. Went very hard to elevation –183.

Sample No. 5, elevation –183 — Stiff light-gray clay. Went fairly easily under 250 lbs. pressure to elevation –204.5.

Sample No. 6, elevation –204.5 — Same as Sample No. 5. Jet continued at about the same rate and pressure to elevation –240± where it began to tighten up.

Sample No. 7, elevation –245 — Stiff light-gray clay with some fine sand. Went at the rate of about 1 foot per jounce under 100–150 lbs. to elevation –265±, then slackened to about 4 inches per jounce under 250 lbs. pressure to elevation –287. Made two attempts to get sample at this elevation but sample pipe came up bent and battered without sample. Put on another length of pipe and churned jet down to refusal at elevation –294. Made two attempts here to get sample but were unsuccessful. Stopped jetting at elevation –294 because no further penetration could be obtained.

* This gravel stratum apparently extended from elevation –150± to elevation –180±.

BORING No. 18

Position—

N. 77° 55′ E., 19,622 feet from Sixteenth street Pier, then 112 feet left.

Goat Island Lighthouse
24° 41′

Western Pacific Mole, Center Line Gable
70° 07′

South Power Tower

Depth of Water—10 feet

Depth of Boring—359 feet

Chronology—

Left Boring No. 17	2.40 p.m.	March 12
Arrived Boring No. 18	4.00 p.m.	March 12
All anchors placed	4.50 p.m.	March 12
Started jetting	11.30 a.m.	March 13
Finished jetting	1.45 p.m.	March 14
Left Boring No. 18	1.45 p.m.	March 17

Total jetting time, 11 hours

Total time at Boring No. 18, 23 hours 25 minutes

Log—

Sample No. 1, elevation –10 — Sandy clay.

Sample No. 2, elevation –39 — Fine, compact brown sand. The jet struck a sand stratum at elevation –36± which continued to elevation –60±.

Broke sample pipe while attempting to get sample at elevation –80. Had to withdraw nozzle. Jetted down again and attempted to get sample at elevation –78, but were unsuccessful. Sand particles adhering to sample pipe showed that we were in fine sand, apparently very compact. When jetting was resumed, pipe was stuck and we broke the runner in attempting to churn it. From elevation –60± to –78± there were two hard strata about 2 feet thick interlaid between the sand.

Sample No. 3, elevation –59 — Yellow sandy clay.

Sample No. 4, elevation –119 — Bluish-gray clay.

Sample No. 5, elevation –160 — Stiff bluish-gray clay. Jet went down about 8 inches per jounce through what we believe to be stiff clay to elevation –200.

Sample No. 6, elevation –200 — Fragments of broken rock. This stratum was about 2 feet thick.

We hit another hard stratum from elevation –206± to elevation –210±; from elevation –210± to elevation –241 we penetrated a stiff clay which was extremely hard to go through.

Sample No. 7, elevation –241 — Stiff, compact, yellow sandy clay. From elevation –241 to –282 the jet went down a little easier, going about 5 inches per jounce under 325 lbs. pressure.

Sample No. 8, elevation –282 — Yellow sandy clay with shattered fragments of rock or gravel. Jet went down hard, about 2 inches per jounce at 300 lbs. pressure to elevation –325.

Sample No. 9, elevation –325 — Sandy yellow clay. Jet continued 2 inches per jounce for about 10 feet and then kept going harder and slower until elevation –359 was reached.

Sample No. 10, elevation –359 — Coarse sand and gravel grading from ¾ inch down, with some stiff light brown clay.

Abandoned Boring No. 18 because the plugged nozzle made it necessary to remove all pipe and we did not deem it advisable to replace pipe to this depth as additional penetration was doubtful.

BORING No. 19

Position—

N. 77° 55′ E., 13,717 feet from Sixteenth street Pier.

Goat Island Lighthouse
40° 34′
High Tank, Oakland Mole
51° 13′
South Power Tower

Depth of Water—33 feet

Depth of Boring—340 feet

Chronology—

Left Boring No. 18	1.45 p.m.	March 17
Arrived Boring No. 19	2.30 p.m.	March 17
Started to place anchors	2.30 p.m.	March 17
All anchors in place	3.05 p.m.	March 17
Started jetting	4.10 p.m.	March 17
Finished jetting	2.50 p.m.	March 18
Started to pull up anchors	7.40 a.m.	March 19
All anchors up	8.10 a.m.	March 19
Left Boring No. 19	8.10 a.m.	March 19

Total boring time, 7 hours

Total time at point, 11 hours

Sample List—

Sample No. 1, elevation –33 — Dark gray sandy clay—surface muck. Apparently hit gravel at elevation –36±. Alternate layers of sand and gravel to elevation –97±. Tried to get a sample at elevation –75±with no success. We know it to be a fine compact sand which continued to elevation –97± where we think we struck clay.

Sample No. 2, elevation –119 — Half of sample pipe filled with clean, fine blue sand and half filled with pure blue clay.

Sample No. 3, elevation –159 — Stiff blue clay.

Sample No. 4, elevation –198 — Stiff blue clay. The jet seemed to be going through clay to elevation –238±. When the union was removed from the top of the jet pipe preparatory to taking Sample No. 5 an artesian flow occurred. This was allowed to run ten minutes before Sample No. 5 was

taken, and became very murky, being practically a saturated solution of fine sand.

Sample No. 5, elevation –240 — Fine gray sand. Artesian flow stopped when sample was taken. When we attempted to resume jetting, the nozzle was found to be plugged.

Sample No. 6, elevation –240 — Material forced up through jet pipe by artesian flow. Jet went down fairly easily to elevation –279, but appeared to be wandering, as if it were in gravel.

Sample No. 7, elevation –279 — Stiff blue clay. Tried to get a sample at elevation –319, but jet pipe was bent and sample pipe would not go through it. Went down to elevation –340, where we were apparently in gravel. The jet had not gone to refusal, but the pipe was badly bent so we stopped here as additional penetration did not seem to warrant additional destruction of equipment; we might have lost the entire jet, and we could get no more samples. When the nozzle was at elevation –340 and the union removed, there was no artesian flow. When the pipe was raised so that the nozzle was at elevation –300±, and the two upper lengths removed, water gushed to a height of 4 inches above the top of the pipe.

Sample No. 8, elevation –300 to –340 — Very stiff dark gray clay, washed up by artesian flow from elevation –300 to –340.

BORING No. 20

Position—

N. 77° 55′ E., 6333 feet from Sixteenth street Pier.

Incinerator Stack
48° 49′

Ferry Building Tower
44° 49′

Goat Island Lighthouse

Depth of Water—57.7 feet

Depth of Boring—263 feet

Chronology—

Left Boring No. 19	8.10 a.m.	March 19, 1930
Arrived at Boring No. 20	9.00 a.m.	March 19, 1930
Started to place anchors	9.00 a.m.	March 19, 1930
All anchors placed	9.25 a.m.	March 19, 1930
Started jetting	11.22 a.m.	March 19, 1930
Finished jetting	10.00 a.m.	March 20, 1930
Started to pull up anchors	11.10 a.m.	March 20, 1930
All anchors up	11.45 a.m.	March 20, 1930
Left Boring No. 20	11.45 a.m.	March 20, 1930

Total jetting time, 6½ hours

Total time at Boring No. 20, 11½ hours

Log—

Sample No. 1, elevation –58 — Blue clay with some sand and broken shells.

Sample No. 2, elevation –105 — Dark gray clay and sand.

Sample No. 3, elevation –149 — Fine gray sand.

Sample No. 4, elevation –190 — Stiff gray clay. Jet went down easily all the way from the surface to elevation –231.5. It apparently wandered, as 40 feet of 1-inch pipe had to be used to get through it and get sample No. 5.

Sample No. 5, elevation –231.5 — Fine gray sand mixed with clay. Jet went down hard to elevation –263. Jet pipe broke at elevation –178± so that we could not get a sample at elevation –263. Abandoned Boring No. 20 because of broken jet pipe.

BORING No. 21

Position—

N. 77° 55′ E., 2767 feet from Sixteenth street Pier, then 67 feet right.

Incinerator Stack

60° 39′

Ferry Building Tower

43° 24′

Goat Island Lighthouse

Depth of Water—39.5 feet

Depth of Boring—293 feet

Chronology—

Left Boring No. 20	11.45	a.m.	March 20, 1930
Arrived at Boring No. 21	12.35	p.m.	March 20, 1930
Started to place anchors	12.35	p.m.	March 20, 1930
All anchors placed	1.30	p.m.	March 20, 1930
Started jetting	8.30	a.m.	March 21, 1930
Finished jetting	11.50	a.m.	March 21, 1930
Started to raise anchors	12.20	p.m.	March 21, 1930
All anchors raised	1.45	p.m.	March 21, 1930
Left Boring No. 21	1.45	p.m.	March 21, 1930

Total jetting time, 3 hours 20 minutes

Total time at point, 10 hours

Log—

Sample No. 1, elevation –39.5	Soft bluish-gray clay.
Sample No. 2, elevation –91	Soft bluish-gray clay.
Sample No. 3, elevation –132	Soft bluish-gray clay.
Sample No. 4, elevation –172	Fairly stiff gray clay.
Sample No. 5, elevation –212	Stiff brown clay.
Sample No. 6, elevation –232	Stiff gray clay.
Sample No. 7, elevation –255	Stiff bluish-gray clay.
Sample No. 8, elevation –293	Broken fragments of rock.

From elevation –262± to –275± we went through a gravel stratum. Then it was apparently clay to elevation –293. Stopped jetting as no additional penetration could be obtained.

BORING No. 22

Position—

N. 42° 24′ E., 1417 feet from Pier 22, then 33 feet right.

Ferry Building Tower

36° 28′

Telephone Building Flag Pole

39° 34′

Pier 26, Flag Pole Center Line Gable

Depth of Water—76 feet

Depth of Boring—189.9 feet

Jetted to elevation	–216.5
Distance jetted	–140.5
Diamond drilled to elevation	–265.9
Distance diamond drilled	49.4
Total distance bored	–189.9

Chronology of Jet Boring—

Left Pier No. 22	12.30	p.m.	March 24, 1930
Arrived at Boring No. 22	1.10	p.m.	March 24, 1930
Started to place anchors	1.10	p.m.	March 24, 1930
All anchors placed	2.19	p.m.	March 24, 1930
Started jetting	11.00	a.m.	March 25, 1930
Finished jetting	1.30	p.m.	March 25, 1930

Chronology of Diamond Drilling Operations—

March 24—Foreman and diamond setter for the Mitchell Diamond Drilling Co. arrived at the work. It was agreed to postpone diamond drilling at Pier 22 until a later date, and to start at Boring No. 22.

March 25—Diamond drilling machinery moved out to the drill barge at Boring No. 22. Started to assemble diamond drill rig and weighed 28 black diamonds and 26 pieces of Thoran steel—4.56 oz. av. of Thoran steel. Diamonds weighed 22.45 carats.

March 26—Set bits and erected platform on top of drill cage.

March 27—Hoisted diamond drilling machinery to platform at 8.40 a.m. Started to lower Thoran bit at 2.45 p.m. Over an hour lost with frozen motor.

March 28—56 feet of drill rods fell to the bottom of the hole during the night (dist. 184 ft.) and broke the drill bit. 2 hours 5 minutes time lost with frozen motor. Recovered the broken bit, replaced it with $1\frac{1}{8}$-inch bit and drilled 1 foot into rock.

March 31—Cage settled 16 inches over the week-end. SW. anchor dragged over the week-end causing breakage of drill rod. Spent the day trying to recover bit and drill rods.

April 1—Drill rods and bit were recovered at 11.30 a.m. Spent the remainder of the day replacing drill rods and casing.

April 2—Replaced the remainder of the drill rods and resumed drilling at 11 a.m., and continued drilling until April 9, 1930.

April 7—Ferryboat "Berkeley" rammed and sank the NE. anchor. After being plumbed, the drill cage settled 3 feet in about 3 seconds. Drilling equipment was undamaged.

April 9—Much difficulty encountered with hole caving in. Stopped diamond drilling at 6.35 p.m. at elevation –265.9.

Sample List— (For materials see log)

Sample No. 1,	elevation –58	
Sample No. 2,	elevation –105	
Sample No. 3,	elevation –149	
Sample No. 4,	elevation –190	
Sample No. 5,	elevation –216.5	
Sample No. 6,	elevation –216.5 to –226	
Sample No. 7,	elevation –226 to –229.5	
Sample No. 8,	elevation –225.3 to –229.5	
Sample No. 9,	elevation –229.5 to –232.8	
Sample No. 10,	elevation –229.5 to –232.8	(Diamond drill cuttings)
Sample No. 11,	elevation –232.8 to –237.5	
Sample No. 12–A,	elevation –237.5 to –242.5	
Sample No. 12–B,	elevation –237.5 to –242.5	
Sample No. 13,	elevation –237.5 to –242.5	(Diamond drill cuttings)
Sample No. 14,	elevation –242.5 to –243.5	
Sample No. 15,	elevation –243.5 to –246	
Sample No. 16,	elevation –246 to –247.5	
Sample No. 17,	elevation –242.5 to –247.5	(Diamond drill cuttings)
Sample No. 18–A,	elevation –247.5 to –251	
Sample No. 18–B,	elevation –251 to –253	
Sample No. 19,	elevation –247.5 to –253	(Diamond drill cuttings)
Sample No. 20,	elevation –253 to –258	
Sample No. 20–A,	elevation –253 to –258	
Sample No. 21,	elevation –253 to –258	(Diamond drill cuttings)
Sample No. 22,	elevation –258 to –261	
Sample No. 22–A,	elevation –261 to –263	
Sample No. 23,	elevation –258 to –263	(Diamond drill cuttings)
Sample No. 24–A,	elevation –263 to –265.9	
Sample No. 24–B,	elevation –263 to –265.9	
Sample No. 25,	elevation –263 to –265.9	(Diamond drill cuttings)

Log—

Elevation	*Material*
–76	
	Soft gray clay
–105	
	Stiff gray clay
–146	
	Stiff gray sandy clay
–216.5	
	Medium hard shale
–226.0	
	Hard sandy shale with veinlets of calcite
–232.8	
	Hard medium grained sandstone
–242.5	

Elevation	*Material*
–242.5	
	Hard shale with streaks of calcite
–243.5	
	Hard fine grained sandstone with veins of calcite
–246	
	Some hard fine-grained sandstone with streaks of calcite and some shale
–247.5	
	Hard shale with veins of calcite
–253	
	Hard sandy shale with veins of calcite
–255	
	Medium hard shale
–261	
	Hard shale with a few streaks of calcite
–265.9	Bottom of boring

BORING No. 23

Position—
N. 42° 24′ E., 4450 feet from Pier 22.
Clock Tower, Schmidt Building
29° 27′
Tower, Ferry Building
24° 17′
Flag Pole, Telegraph Hill.

Depth of Water—66.5 feet
Depth of Boring—169.6 feet

Jetted to elevation	–140
Distance jetted	73.5 feet
Diamond drilled to elevation	–169.6
Distance diamond drilled	29.6 feet
Depth of boring	–169.6
Total distance bored	103.1 feet

Chronology—

Left Boring No. 22	3.55 p.m. April 10, 1930
Arrived at Boring No. 23	6.10 a.m. April 14, 1930
Started to place anchors	6.10 a.m. April 14, 1930
All anchors placed	2.45 p.m. April 15, 1930
Started jetting	10.40 a.m. April 16, 1930
Finished jetting	1.55 p.m. April 16, 1930
Prepared to drill	2.00 p.m. April 16, 1930 to 10.00 a.m. April 21, 1930
Diamond drilling	10.00 a.m. April 21, 1930 to 11.00 a.m. April 24, 1930

Dismantling diamond drill 11.30 a.m. to 4 p.m. April 24, 1930
Shifted to Boring No. 23 without raising anchors
Left Boring No. 23 11.00 a.m. April 25, 1930
Total jetting time, 3 hours
Total drilling time, 6 days
Total time at point, 9½ working days
Note—Left Pier 42 at 5.10 a.m. April 14, 1930

List of Samples—

Sample No. 1,	elevation –66.5	Surface muck, dark gray sandy clay.
Sample No. 2,	elevation –98.5	Gray clay and sand, lighter in color and with a greater sand content than Sample No. 1.
	Elevation –110	Struck stiff material which continued to elevation –120.
Sample No. 3,	elevation –120	Stiff, light gray clay, with a small amount of fine sand, which kept increasing in stiffness until rock was reached at elevation –137. Forced jet down to elevation –140, and stopped jetting.
Sample No. 4,	elevation –140	Particles of broken shale in light gray clay.

Sample No. 5,	elevation −140 to −143	Shale broken up by chopping bit.
Sample No. 6,	elevation −140 to −146.4	Shale.
Sample No. 7,	elevation −140 to −146.4	Diamond drill cuttings.
Sample No. 8–A,	elevation −146.4 to −147.5	Shale with few veinlets of calcite.
Sample No. 8–B,	elevation −147.5 to −149.5	Shale, but more broken up than Sample No. 8–A.
Sample No. 8–C,	elevation −146.4 to −149.5	Diamond drill cuttings.
Sample No. 9–A,		
Sample No. 9–B,		
Sample No. 9–C,	elevation −149.5 to −154.4	Shale with veinlets of calcite.
Sample No. 10–A,		
Sample No. 10–B,		
Sample No. 10–C,	elevation −154.4 to −159.5	Shale with veinlets of calcite.
Sample No. 11–A,		
Sample No. 11–B,		
Sample No. 11–C,		
Sample No. 11–D,	elevation −159.5 to −164.6	Shale with patches of calcite.

Log—

From elevation −66.5	to elevation −110	Soft gray sandy clay.
From elevation −110	to elevation −120	Stiff light gray clay.
From elevation −120	to elevation −137	Stiff gray sandy clay.
From elevation −137	to elevation −146.4	Medium hard shale.
From elevation −146.4	to elevation −169.6	Hard shale with a few veinlets of calcite (this increased in hardness and size and quantity of calcite streaks with depth. Maximum core 2 inches at top and 8 inches at bottom).

BORING No. 24

Position—

N. 42° 24′ E., 4567 feet from Pier 22, then 33 feet right.
About 150 feet east of Boring No. 23
Clock Tower, Schmidt Building
28° 51′
Tower, Ferry Building
24° 06′

Flag Pole, Telegraph Hill

Depth of Water—67.7 feet
Depth of Boring—130.3 feet
Total distance jetted—62.6 feet

This boring was made without shifting the anchors from their positions for Boring No. 23. The barge was moved by taking up on the east anchor lines and paying out the west anchor lines. It was made to check the surface elevation of the rock as found at Boring No. 23 and to determine its slope.

We started to pull up the drill cage and prepare to move from Boring No. 23 at 7.30 a.m., and had our jetting completed at Boring No. 24 by 10.15 a.m. Left Boring No. 24 at 10.45 a.m.

No samples of material were taken.

Hit rock at elevation −127.3, and penetrated 3 feet with jet.

BORING No. 25

Position—

N. 42° 24′ E., 4267 feet from Pier 22.
About 200 feet west of Boring No. 23
Clock Tower, Schmidt Building
30° 24′
Tower, Ferry Building

Tower, Ferry Building
24° 20½′
Flag Pole, Telegraph Hill

Depth of Water—67 feet
Depth of Boring—146 feet
Total distance jetted—79 feet
Anchors in same position as for Boring No. 23. Moved by adjusting anchor lines.

Chronology—

Left Boring No. 24 at	10.45	a.m. April	25, 1930
Arrived Boring No. 25 at	11.05	a.m. April	25, 1930
Started jetting	11.40	a.m. April	25, 1930
Finished jetting	1.20	p.m. April	25, 1930
Started to raise anchors	2.35	p.m. April	25, 1930

Log—
No samples were taken. Clay to elevation –135. Hard stratum, probably shale, to elevation –137. Hit rock at elevation –145 and penetrated to elevation –146.

BORING No. 26

Position—
N. 42° 24′ E., 7.333 feet from Pier 22, then 33 feet right.
Middle "C" in G. W. P. Sign, Goat Island
104° 27′
Goat Island Lighthouse
21° 00′
Western Pacific Mole

Depth of Water—85.2 feet
Depth of Boring—194.7 feet

Jetted to elevation	–133.3
Distance jetted	48.1 feet
Diamond drilled to elevation	–194.7
Distance diamond drilled	61.4 feet
Total depth bored	–109.5
Elevation of bottom boring	–194.7

Chronology—

Left Boring No. 25	7.18	a.m. April	28, 1930
Arrived at Boring No. 26	7.45	a.m. April	28, 1930
Started to place anchors	8.00	a.m. April	28, 1930
All anchors placed	11.00	a.m. April	28, 1930
Started jetting	3.00	p.m. May	1, 1930
Finished jetting	4.00	p.m. May	1, 1930
*Started jetting	7.30	a.m. May	5, 1930
Finished jetting	9.00	a.m. May	5, 1930
Started drilling preparations	9.00	a.m. May	5, 1930
Finished drilling preparations	4.00	p.m. May	5, 1930
Started diamond drilling	12.00	noon May	6, 1930
Finished diamond drilling	4.00	p.m. May	21, 1930
Dismantling diamond drill	7.30	a.m. to	
	9.30	a.m. May	22, 1930
Did not raise anchors			
Left Boring No. 26	1.00	p.m. May	22, 1930

Jetting time, 1½ hours
Drilling time, 11½ days
Total time at point, 18½ days
* Second run. See chronology following.

Chronology of Diamond Drilling Operations—
Job held up because of insufficient drill cage, April 29 and 30. Jetted hole to elevation –137, where hard material was struck (May 1). The cage settled 8 feet during the night and was too low for drilling operations May 2. Erected timber footing on bottom of drill cage to keep it from sinking in the mud. Could not get back on the hole we had drilled, so a new hole was jetted down to rock at elevation –133.3, 7.30 to 9 a.m., May 5, 1930.
Erected platform 10 a.m. to 1.30 p.m. May 5, placing drill rig on platform and prepared to drill 1.30 p.m. to 4 p.m. May 5. Attempted to drill with a steel bit in the afternoon of May 6 and the morning of May 7. Destroyed two bits without obtaining any penetration.

Fired a charge of 14 sticks of 60 per cent dynamite in the bottom of the hole and cleaned it out with the chopping bit May 8 and went down with a diamond bit.

Finished diamond drilling 4 p.m. May 21, 1930.

Dismantled drill rig 7.30 to 9.30 a.m. May 22, 1930.

Moved off of Boring No. 26 at 1 p.m. May 22, 1930.

Sample List—

Sample No. 1,	elevation −85.2	Surface muck.
Sample No. 2,	elevation −124	Stiff blue sandy clay.
Sample No. 3,	elevation −133.3 to −134.5	Diamond drill cuttings.
Sample No. 4,	elevation −135 to −137	Chert, very hard.
Sample No. 4–A,	elevation −135 to −137	Diamond drill cuttings.
Sample No. 5–A,	elevation −137 to −139	
Sample No. 5–B,	elevation −137 to −139	Same as No. 4 and No. 4–A.
Sample No. 6,	elevation −139 to −139.4	Chert, very hard.
Sample No. 7,	elevation −139 to −139.4	Diamond drill cuttings.
Sample No. 8,	elevation −139.4 to −144.5	Stiff clay intermixed with fragments of shale.
Sample No. 9,	elevation −144.5 to −150	Pieces of hard rock from a run of 5½ feet through very soft shale with occasional streaks of hard sandstone. Only samples of the rock came up in the core barrel, the clay being washed away.
Sample No. 10,	elevation −144.5 to −150	Diamond drill cuttings.
Sample No. 11,	elevation −150	Fine green sand.
Sample No. 12,	elevation −150 to −156	Diamond drill cuttings—no core.
Sample No. 13,	elevation −156	Sand washed up from elevation −156.
Sample No. 14,	elevation −156 to −166	Sand washed up in diamond drilling operations.
Sample No. 15,	elevation −166 to −170.2	Soft serpentine.
Sample No. 16,	elevation −166 to −170.2	Diamond drill cuttings.
Sample No. 17,	elevation −170.2 to −174.8	Soft serpentine.
Sample No. 18–A,	elevation −174.8	Soft serpentine about the consistency of a very stiff clay intermixed with hard pieces of serpentine.
Sample No. 18–B,	elevation −180	
Sample No. 19,		Hard chert with layers of soft shale.
Sample No. 19–A,	elevation −180 to −184.1	
Sample No. 20,	elevation −184.1 to −188.6	Hard shale interlaid with 2-inch or 3-inch layers of soft shale at about 1 foot intervals.
Sample No. 21,	elevation −180 to −188.6	Diamond drill cuttings.
Sample No. 22,	elevation −188.6 to −194	Soft serpentine with a few small pieces of hard serpentine.
Sample No. 23,	elevation −188.6 to −194	Diamond drill cuttings.
Sample No. 24,	elevation −194 to −194.7	Same as Sample No. 22.

Log—

Elevation	*Material*
−85.2	
	Soft muck
−114	
	Stiff blue sandy clay
−133.3	
	Shale, medium hard
−134.5	
	Hard chert
−139.4	
	Clay intermixed with fragments of shale
−144.5	
	Very soft sandstone interlaid with 2-inch and 3-inch layers of hard sandstone
−150	

Elevation	*Material*
–150	
	Fine greenish black sand.
–166	
	Soft serpentine.
–174.8	
	Soft serpentine with pieces of hard serpentine.
–180	
	Soft shale with patches of chert.
–184.1	
	Hard shale interlaid with 2-inch or 3-inch layers of soft shale at about 1 foot intervals.
–188.6	
	Hard serpentine with a few thin layers of soft serpentine.
–194.7	Bottom of boring.

BORING No. 27

Position—
N. 42° 24′ E., 7423 feet from Pier 22.
90 feet nearer to Goat Island than Boring No. 26
Clock Tower, Schmidt Building
19° 22½′
Tower, Ferry Building
21° 23′
Flag Pole, Telegraph Hill

Depth of Water—79 feet
Depth of Boring—126 feet
Chronology—

Left Boring No. 26	1.00 p.m.	May 22, 1930
In position at No. 27	1.40 p.m.	May 22, 1930
Anchors were not moved		
Started jetting	3.25 p.m.	May 22, 1930
Finished jetting	4.40 p.m.	May 22, 1930
Left Boring No. 27	10.15 a.m.	May 23, 1930

Jetting time, 1 hour 15 minutes
Time at point, ½ day
Log—

Elevation	*Material*
–79	
	Soft muck.
–96	
	Stiff blue clay.
–120	
	Rock.
–126	Bottom of boring.

Sample No. 1, elevation –112 Stiff blue clay.
Struck rock at elevation –120, and penetrated to elevation –126 with the jet.

BORING No. 28

Position—
N. 42° 24′ E., 7243 feet from Pier 22, then 33 feet right.
90 feet toward San Francisco from Boring No. 26
Clock Tower, Schmidt Building
19° 54½′
Tower, Ferry Building
21° 34′
Telegraph Hill Flag Pole

Depth of Water—95 feet
Depth of Boring—166 feet
Chronology—

Left Boring No. 27	10.15 a.m.	May 23, 1930
In position at Boring No. 28	10.30 a.m.	May 23, 1930
Did not move the anchors		
Started jetting	11.00 a.m.	May 23, 1930
Finished jetting	12.15 p.m.	May 23, 1930

Started to raise anchors 8.00 a.m. May 26, 1930
All anchors up 1.50 p.m. May 26, 1930
Left Boring No. 28 1.50 p.m. May 26, 1930
Jetting time, 1 hour 15 minutes
Total time at point, 12 hours

Log—

Elevation	*Material*
–95	
	Soft muck
–120	
	Stiff light gray clay
–160	
	Rock
–166	Bottom of Boring

Struck rock at elevation –160 and penetrated to –166 with jet.
Sample No. 1, elevation –150. Stiff light gray clay.
Brought up a fragment of rock with sample pipe when we attempted to get a sample at elevation –166.

BORING No. 29

Position—
Two feet out from the center of the end of Pier 21.

Depth of Water—39.2 feet
Depth of Boring—211 feet
Chronology—
Left Pier 22 8.50 a.m. May 28, 1930
Arrived Pier 21 10.05 a.m. May 28, 1930
Started jetting 11.30 a.m. May 28, 1930
Finished jetting 3.00 p.m. May 28, 1930
Left Pier 21 6.30 a.m. May 29, 1930
Jetting time, 3 hours
Total time at point, 1 day

Log—

Elevation	*Material*
–39.2	
	Soft muck
–75±	
	Soft light gray clay
–100	
	Stiff clay
–120	
	Sand, gravel and shells
–211	Hit rock at elevation –211

Sample List—

Sample No. 1, elevation	–39.2	Surface muck.
Sample No. 2, elevation	–86	Soft light gray clay.
Sample No. 3, elevation	–128.6	Gravel, sand and yellow clay intermixed.
Sample No. 4, elevation	–168.5	Sand.
Sample No. 5, elevation	–189	Clay, sand and shells intermixed.
Sample No. 6, elevation	–205	Sand and shells.

BORING No. 30

Position—
572 feet west of the east end and 16.5 feet north of the north side of Pier 24.

Depth of Water—25.8 feet
Depth of Boring—122.3 feet
Chronology—
Left Pier No. 21 6.30 a.m. May 29, 1930
Arrived at Boring No. 30 7.30 a.m. May 29, 1930
Started jetting 9.00 a.m. May 29, 1930
Finished jetting 11.30 a.m. May 29, 1930
Left Boring No. 30 2.00 p.m. May 29, 1930
Boring time, 2½ hours
Total time at Boring No. 30, 7½ hours

Log—

Elevation	*Material*
–25.8	
	Soft clay
–85±	
	Stiff clay mixed with coarse sand and gravel
–120±	
	Rock
–122.3	Bottom of boring

Sample List—

Sample No. 1, elevation –25.8	Surface muck.
Sample No. 2, elevation –66	Soft light gray clay intermixed with coarse sand and small pebbles.
Sample No. 3, elevation –107.6	Stiff light gray clay intermixed with coarse sand.
Sample No. 4, elevation –122.3	Rock fragments.

BORING No. 31

Position—

N. 73° 20′ E., 2833 feet from Pier 18.
Clock Tower, Schmidt Building
16° 22′
Telephone Building, Flag Pole
27° 13½′
Tower, Ferry Building

Depth of Water—67 feet
Depth of Boring—200 feet

Chronology—

Left Pier 22	7.35 a.m. June 2, 1930
Arrived at Boring No. 31 and started to place anchors at	9.00 a.m. June 2, 1930
All anchors placed and barge in position at	11.00 a.m. June 2, 1930
Started jetting	2.30 p.m. June 2, 1930
Finished jetting	10.00 a.m. June 3, 1930

Jetted for 1 hour on June 2
Finished jetting at 10.00 a.m. after 2½ hours on June 3d
Left Boring No. 31 at 11 a.m. June 4, 1930
Jetting time, 3½ hours
Total time at Boring No. 31, 2½ days

Sample List—

Sample No. 1, elevation –67	Surface muck, yellowish gray sandy clay, dark gray muck, and a few fragments of shells; very soft.
Sample No. 2, elevation –88.5	Soft gray sandy clay.
Sample No. 3, elevation –102	Firm gray sandy clay. Not so soft as Sample No. 2.
Sample No. 4, elevation –125	Soft yellowish gray clay. Struck this at –103±.
Sample No. 5, elevation –168	Stiff gray clay mixed with fine sand. Struck this at –148.
Sample No. 6, elevation –200	Fragments of hard shale. Struck this at elevation –196.5.

Log—

Elevation	*Material*
–67	
	Soft clay and sand
–103	
	Soft yellowish gray clay
–148	
	Stiff gray sandy clay
–196.5	
	Hard shale
–200	Bottom of boring

BORING No. 32

Position—
N. 42° 24′ E., 3833 feet from Pier 22, then 58 feet right.
Clock Tower, Schmidt Building
32° 58′
Tower, Ferry Building
24° 02′
Telegraph Hill, Flag Pole

Depth of Water—64 feet
Depth of Boring—155.4 feet
Chronology—

Left Boring No. 31 at	11.00	a.m. June 4, 1930
Arrived Boring No. 32 at	11.20	a.m. June 4, 1930
Started placing anchors	11.20	a.m. June 4, 1930
All anchors placed	2.35	p.m. June 4, 1930
Started jetting	8.45	a.m. June 5, 1930
Finished jetting	10.30	a.m. June 5, 1930
Left Boring No. 32 at	8.00	a.m. June 6, 1930

Jetting time, 1 hour 45 minutes
Total time at point, 1½ days
Sample List—

Sample No. 1, elevation –64	Soft surface muck consisting of yellowish-gray sandy clay and shells.
Sample No. 2, elevation –108	Soft gray sandy clay.
Sample No. 3, elevation –150	Stiff light gray clay.
Sample No. 4, elevation –155.4	Rock fragments (shale).

Log—

Elevation	*Material*
–64	
	Soft sandy clay
–135	
	Stiff light gray clay, represented by Sample No. 3
–152	
	Rock
–155.4	Bottom of boring

BORING No. 33

Position—
N. 42° 24′ E., 3533 feet from Pier 22, then 33 feet left.
Flag Pole, Pier 26
43° 08′
Tower, Ferry Building
24° 34′
Telegraph Hill, Flag Pole

Depth of Water—68 feet
Depth of Boring—186.7 feet
Chronology—

Left Boring No. 32	7.45	a.m. June 6, 1930
Arrived Boring No. 33	8.00	a.m. June 6, 1930
Anchors placed	6.00	a.m. to
(only 2 anchors shifted)	7.45	a.m. June 6, 1930
Started jetting	9.45	a.m. June 6, 1930
Finished jetting	11.35	a.m. June 6, 1930
Left Boring No. 33 at	3.45	p.m. June 6, 1930

Jetting time, 1 hour 50 minutes
Total time at point, 8 hours
Sample List—

Sample No. 1, elevation –68	Surface muck, firm gray sandy clay and shells.
Sample No. 2, elevation –111	Firm gray clay.
Sample No. 3, elevation –149	Stiff gray clay.

Log—

Elevation	*Material*
–68	
	Firm gray sandy clay and shells (surface muck) which graded into firm gray clay in about ten feet
–80	

Elevation	*Material*
–80	
	Firm gray clay
–135	
	Stiff gray clay
–186	Rock

Hit rock at elevation –186 and penetrated to –186.7. No sample could be obtained of this rock because the jet pipe was bent.

BORING No. 34

Position—
N. 87° 00′ E., 7033 feet from Pier 32.
Clock Tower, Schmidt Building
24° 47′
Tower, Ferry Building
67° 49′
Goat Island Lighthouse

Depth of Water—58 feet
Depth of Boring—307 feet
Chronology—

Left Pier 34 at	7.30 a.m.	June 9, 1930
Started to place anchors	10.30 a.m.	June 9, 1930
All anchors placed	11.45 a.m.	June 9, 1930
Started jetting	1.50 p.m.	June 9, 1930
Finished jetting	1.00 p.m.	June 10, 1930
Left Boring No. 34	8.30 a.m.	June 11, 1930

Jetting time, 7 hours
Total time at point, 2 days
Sample List—

Sample No. 1, elevation –58	Soft gray sandy clay.
Sample No. 2, elevation –102	Soft gray clay.
Sample No. 3, elevation –124	Soft gray sandy clay.
Sample No. 4, elevation –143.5	Yellowish gray sandy clay.
Sample No. 5, elevation –184	Very compact stiff gray sandy clay.
Sample No. 6, elevation –222 to –226	Gray sand.
Sample No. 7, elevation –266	Soft yellow sandy clay.

Log—

Elevation	*Material*
–58	
	Soft gray sandy clay
–102	
	Soft gray clay
–124	
	Soft gray sandy clay
–143.5	
	Yellowish gray sandy clay
–160	
	Very compact stiff gray sandy clay
–222	
	Gray sand
–255	
	Soft yellow sandy clay
–300	
	Stiff clay
–305	
	Rock
–307	Bottom of boring

BORING No. 35

Position—
N. 87° 00′ E., 12,950 feet from Pier 32, then 50 feet right.
Goat Island Lighthouse
61° 57′
High Tank, Oakland Mole

High Tank, Oakland Mole

59° 55'

North Power Tower

Depth of Water—27 feet
Depth of Boring—300.5 feet
Chronology—

Left Boring No. 34	8.30 a.m.	June 11, 1930
Arrived Boring No. 35	9.30 a.m.	June 11, 1930
Started to place anchors	9.40 a.m.	June 11, 1930
All anchors placed	10.35 a.m.	June 11, 1930
Started jetting at	2.00 p.m.	June 11, 1930
Finished jetting at	10.30 a.m.	June 12, 1930
Started to raise anchors	12.45 p.m.	June 12, 1930
All anchors up	1.20 p.m.	June 12, 1930
Left Boring No. 35	1.20 p.m.	June 12, 1930

Total jetting time, 4½ hours
Total time at point, 1½ days

Sample List—

Sample No. 1, elevation –27	Soft surface muck, yellowish gray sandy mud.
Sample No. 2, elevation –72	Soft yellowish gray clay.
Sample No. 3, elevation –112.5	Same as No. 2.
Sample No. 4, elevation –133.6	Stiff gray clay.
Sample No. 5, elevation –158	Same as No. 4.
elevation –199	Attempted to get a sample at elevation –199 but were unsuccessful. Some gray oily sand came up sticking to the sample pipe.
Sample No. 6, elevation –240	Gray sand.
Sample No. 7, elevation –279	Very stiff gray clay.
	Struck rock at elevation –299 and penetrated to elevation –300.5 but were unable to obtain a sample of the rock because the pipe was broken.

Log—

Elevation –27 to –40	Yellowish gray sandy mud
Elevation –40 to –132	Soft yellowish gray clay
Elevation –132 to –155	Stiff gray clay
	Artesian flow of water at elevation –155
Elevation –155 to –175	Gravel
Elevation –175 to –180	Stiff clay
Elevation –180 to –240	Alternate layers of hard and soft material, probably alternate layers of sand or gravel and clay (could obtain no sample)
Elevation –240 to –299	Very stiff gray clay
Elevation –299 to –300.5	Rock
–300.5	Bottom of boring

BORING No. 36

Position—

16.3 feet east of the bulkhead and 9 feet south of the south side of Pier 32.

Depth of Water—20 feet
Depth of Boring—162.8 feet
Chronology—

Left Boring No. 35	1.20 p.m.	June 12, 1930
Arrived Boring No. 36	2.25 p.m.	June 12, 1930
Started jetting	3.00 p.m.	June 12, 1930
Finished jetting	9.30 a.m.	June 13, 1930
Left Boring No. 36	10.20 a.m.	June 13, 1930

Jetting time, 3¼ hours
Total time at point, 3 hours 40 minutes

Sample List—

Sample No. 1, elevation –20	Surface muck consisting of soft yellow sandy mud.
Sample No. 2, elevation –71.5	Very compact fine yellow sand.
Sample No. 3, elevation –115	Very stiff yellow sandy clay.
Sample No. 4, elevation –162.8	Yellow sandstone, similar to Rincon Hill.

Log—

Elevation –20 to –45	Yellow sandy mud

Elevation	−45 to −70	Soft yellow sandy clay
Elevation	−70 to −76	Stiff yellow sandy clay
Elevation	−76 to −108	Sand
Elevation	−108 to −161	The material graded from very stiff sandy clay to firm sandstone

BORING No. 37

Position—
N. 87° 00′ E., 3700 feet from Pier 32.
Clock Tower, Schmidt Building
36° 02½′
Ferry Building, Tower
83° 11′
Goat Island Lighthouse

Depth of Water—61 feet
Depth of Boring—239.5 feet
Chronology—

Left Pier 32	7.35 a.m.	June 16, 1930
Arrived at Boring No. 37	8.30 a.m.	June 16, 1930
Started to place anchors	8.30 a.m.	June 16, 1930
All anchors placed	11.15 a.m.	June 16, 1930
Started jetting	12.30 p.m.	June 16, 1930
Finished jetting	8.45 a.m.	June 17, 1930
Started to raise anchors	8.45 a.m.	June 17, 1930
All anchors raised	11.35 a.m.	June 17, 1930
Left Boring No. 37	11.35 a.m.	June 17, 1930

Total jetting time, 4¾ hours
Total time at point, 12 hours

Sample List—

Sample No. 1, elevation −61	Surface muck consisting of soft gray clay.
Sample No. 2, elevation −97	Soft gray clay.
Sample No. 3, elevation −148	Clay mixed with coarse sand and shells.
Sample No. 4, elevation −191	Stiff gray clay.
Sample No. 5, elevation −231	Very stiff sandy clay.
Sample No. 6, elevation −239.5	Rock fragments ground up and broken by jet.

Log—

Elevation	−61 to −97	Soft gray clay
Elevation	−97 to −143	Clay mixed with coarse sand and shells
Elevation	−143 to −229	Stiff gray clay
Elevation	−229 to −238	Very stiff sandy clay
Elevation	−238 to −239.5	Rock
Elevation	−239.5	Bottom of boring

BORING No. 38

Position—
N. 87° 00′ E., 5483 feet from Pier 32.
Clock Tower, Schmidt Building
28° 55′
Ferry Building, Tower
76° 20′
Goat Island Lighthouse

Depth of Water—62 feet
Depth of Boring—255 feet
Chronology—

Left Boring No. 37	11.35 a.m.	June 17, 1930
Arrived Boring No. 38	11.45 a.m.	June 17, 1930
Started to place anchors	11.45 a.m.	June 17, 1930
All anchors placed	2.00 p.m.	June 17, 1930
Started jetting	3.25 p.m.	June 17, 1930
Finished jetting	9.40 a.m.	June 18, 1930
Started to raise anchors	12.45 p.m.	June 18, 1930
All anchors raised	1.35 p.m.	June 18, 1930
Left Boring No. 38	1.35 p.m.	June 18, 1930

Jetting time, 3 hours
Total time at point, 9½ hours

Sample List—

Sample No. 1, elevation −62	Sand.
Sample No. 2, elevation −104.3	Soft gray clay.
Sample No. 3, elevation −148	Very fine sand with a small percentage of clay.
Sample No. 4, elevation −190	Firm blue clay.
Sample No. 5, elevation −231.5	Stiff clay with fragments of hard shale.
Sample No. 6, elevation −255	Fragments of hard shale.

Log—

Elevation −62 to −136	A layer of sand about one foot thick was found at the surface which quickly graded into a soft gray clay. This extended to elevation −136.
Elevation −136 to −140	Soft sandstone
Elevation −140 to −175	Sand and gravel
Elevation −175 to −215	Firm blue clay
Elevation −215 to −254.5	A layer of hard shale, about 2 feet thick was encountered at elevation −215 to −217±. Below this was stiff blue clay with streaks of shale to elevation −254.5.
Elevation −254.5 to −255	Hard shale.
Elevation −255	Bottom of boring.

BORING No. 39

Position—

N. 45° 00′ E., 1683 feet from Hunter Point Dry-dock.
Chimney, Hunter Point
58° 56′
Center Line, Gas Tank, Army St.
30° 09′
Telephone Bldg., Flag Staff

Depth of Water—69 feet
Depth of Boring—369 feet
Chronology—

Left Boring No. 38	1.35 p.m. June 18, 1930
Arrived Boring No. 39	2.40 p.m. June 18, 1930
Started to place anchors	2.40 p.m. June 18, 1930
All anchors placed	4.20 p.m. June 18, 1930
Started jetting	8.20 a.m. June 19, 1930
Finished jetting	1.20 p.m. June 19, 1930
Started to raise anchors	7.30 a.m. June 20, 1930
All anchors raised	8.30 a.m. June 20, 1930
Left Boring No. 39	8.30 a.m. June 20, 1930

Jetting time, 4½ hours
Total time at Boring No. 39, 12½ hours

Sample List—

Sample No. 1, elevation −69	Surface muck consisting of soft yellowish gray clay.
Sample No. 2, elevation −106	Soft yellowish gray clay mixed with a small amount of sand and shells.
Sample No. 3, elevation −127	Firm yellowish gray sandy clay.
Sample No. 4, elevation −148	Stiff gray clay.
Sample No. 5, elevation −190	Stiff gray sandy clay.
Sample No. 6, elevation −232	Very stiff gray clay.
Sample No. 7, elevation −274.5	Stiff light gray clay.
Sample No. 8, elevation −317	Firm yellow sandy clay.
Sample No. 9, elevation −358.5	Stiff gray clay.
Sample No. 10, elevation −369	Fragments of hard shale mixed with clay.

Log—

Elevation −69 to −125	Soft yellowish gray clay which graded into a firm yellowish gray sandy clay at elevation −125.
Elevation −125 to −137	Firm yellowish gray sandy clay
Elevation −137 to −236	Very stiff gray clay
Elevation −236 to −261	Soft rock
Elevation −261 to −310±	Stiff light gray clay
Elevation −310± to −320±	A stratum of firm yellowish sandy clay
Elevation −320± to −369	Stiff gray clay
Elevation −369	Hard shale, bottom of boring

BORING No. 40

Position—
N. 45° 00′ E., 3500 feet from Hunter Point Dry-dock.
Hunter Point Stack 58° 08′
Gas Tank, Army Street 40° 14′
Ferry Building, Tower

Depth of Water—61 feet
Depth of Boring—314 feet
Chronology—

Left Boring No. 39	8.30 a.m.	June 20, 1930
Arrived Boring No. 40	8.40 a.m.	June 20, 1930
Started to place anchors	8.40 a.m.	June 20, 1930
All anchors placed	11.20 a.m.	June 20, 1930
Started jetting	1.30 p.m.	June 20, 1930
Finished jetting	11.00 a.m.	June 23, 1930
Started raising anchors	5.30 a.m.	June 24, 1930
Left Boring No. 40	6.55 a.m.	June 24, 1930

Jetting time, 6½ hours
Total time at Boring No. 40, 17 hours 25 minutes

Sample List—

Sample No. 1, elevation –61	Surface muck, consisting of very soft light gray clay.
Sample No. 2, elevation –110	Soft light gray clay.
Sample No. 3, elevation –129	Fine gray sand mixed with a small amount of clay.
Sample No. 4, elevation –149	Gravel.
Sample No. 5, elevation –188.5	Stiff gray clay.
Sample No. 6, elevation –217	Light gray saudy clay.
Sample No. 7, elevation –232	Stiff gray clay.
Sample No. 8, elevation –261.5	Rock fragments broken up by jet. Sandstone and a small amount of calcite.
Sample No. 9, elevation –273	Stiff yellow sandy clay; almost like hardpan.
Sample No. 10, elevation –312	Stiff yellowish-gray clay.
Sample No. 11, elevation –314	Soft sandstone ground up by nozzle.

Log—

Elevation –61 to –120	Very soft light gray clay
Elevation –120 to –141	Fine gray sand mixed with a small amount of clay
Elevation –141 to –147	Sand
Elevation –147 to –157	Gravel
Elevation –157 to –178	Sandy clay
Elevation –178 to –200	Stiff gray clay
Elevation –200 to –212	Soft rock, probably serpentine
Elevation –212 to –220	Light gray sandy clay
Elevation –220 to –246	Stiff gray clay
Elevation –246 to –258	Stiff gray clay containing layers of rock about 1 foot thick
Elevation –258 to –270	Cemented gravel
Elevation –270 to –314	Stiff yellow sandy clay interlaid with strata of soft yellow sandstone from 1 to 5 feet thick.
Elevation –314	Soft yellow sandstone, bottom of boring.

BORING No. 41

Position—
Fifty feet north of the north end and 8 feet west of the center line of the first concrete pier west of the west end of the lift span, San Mateo-Hayward Bridge.

Depth of Water—45 feet
Depth of Boring—233.5 feet
Chronology—

Left Boring No. 40	6.55 a.m.	June 24, 1930
Arrived Boring No. 41	9.45 a.m.	June 24, 1930
All anchors placed	10.45 a.m.	June 24, 1930
Started jetting	12.30 p.m.	June 24, 1930
Finished jetting	9.45 a.m.	June 25, 1930
Started to raise anchors	11.45 a.m.	June 25, 1930

All anchors raised 12.30 p.m. June 25, 1930
Left Boring No. 41 12.30 p.m. June 25, 1930
Jetting time, 5¾ hours
Total time at Boring No. 41, 15 hours

Sample List—

Sample No. 1, elevation	−45	Gray sand, clay and shells; about 50 per cent sand.
Sample No. 2, elevation	−74	Light gray sandy clay.
Sample No. 3, elevation	−88.5	Gravel.
Sample No. 4, elevation	−96	Firm yellowish-gray clay.
Sample No. 5, elevation	−100	Same as Sample No. 4.
Sample No. 6, elevation	−118	Stiff gray clay.
Sample No. 7, elevation	−158	Stiff gray clay.
Sample No. 8, elevation	−177	Very compact, stiff, gray, sandy clay.
Sample No. 9, elevation	−198.5	Stiff gray clay.
Sample No. 10, elevation	−221	Cemented sand and gravel.
Sample No. 11, elevation	−233.5	Soft sandstone pulverized by nozzle.

Log—

Elevation	−45	to −72	Gray sandy clay; about 50 per cent sand
Elevation	−72	to −84	Light gray sandy clay
Elevation	−84	to −96	Compact gravel
Elevation	−96	to −100	Firm yellowish gray clay
Elevation	−100	to −174	Stiff gray clay
Elevation	−174	to −182	Compact, stiff, gray sandy clay
Elevation	−182	to −212	Very stiff gray clay
Elevation	−212	to −231.5	Alternate layers, 1 to 5 feet thick of stiff clay and cemented gravel.
Elevation	−231.5	to −233.5	Soft sandstone
Elevation	−233.5		Bottom of boring

MECHANICAL ANALYSES OF SAMPLES

Physical tests of the samples of all material obtained during the boring operations are being made by Prof. George D. Louderback, consulting geologist of the University of California.

All of the tests are not completed at this time. Following are the results of mechanical analyses of such samples as are available at this time. (July 17, 1930.)

BORING No. 1

Sample No. 2

Greater than	2mm; less than	5mm.	= 0.0325 grs.	=	0.325%
Greater than	1mm; less than	2mm.	= 0.0443 grs.	=	0.443%
Greater than	½mm; less than	1mm.	= 0.2685 grs.	=	2.685%
Greater than	1/20mm; less than	½mm.	= 2.6916 grs.	=	26.916%
Less than	1/20mm		= 6.9631 grs.	=	69.631%
Total			10.0000 grs.		100.000%

Sample No. 3

Greater than	1/20mm; less than	½mm.	= 0.6970 grs.	=	6.970%
Less than	1/20mm		= 9.3030 grs.	=	93.030%
Total			10.0000 grs.		100.000%

Sample No. 4

(Fragments of pipe scale					
Greater than	½mm.)		= 0.4210 grs.	=	4.210%
Greater than	1/20mm; less than	½mm.	= 0.7405 grs.	=	7.405%
Less than	1/20mm		= 8.8385 grs.	=	88.385%
Total			10.0000 grs.		100.000%

BORING No. 2

Sample No. 2

Greater than	1/20mm; less than	½mm.	= 5.2685 grs.	=	52.685%
Less than	1/20mm		= 4.7315 grs.	=	47.315%
Total			10.0000 grs.		100.000%

BORING No. 4

Sample No. 4

Greater than	1/20mm; less than	½mm.	= 2.1835 grs.	=	21.835%
Less than	1/20mm		= 7.8165 grs.	=	78.165%
Total			10.0000 grs.		100.000%

BORING No. 9

Sample No. 2

Greater than	2mm; less than	5mm.	= 0.0688 grs.	=	0.688%
Greater than	1mm; less than	2mm.	= 0.0817 grs.	=	0.817%
Greater than	½mm; less than	1mm.	= 0.0770 grs.	=	0.770%
Greater than	1/20mm; less than	½mm.	= 4.3181 grs.	=	43.181%
Less than	1/20mm		= 5.4544 grs.	=	54.544%
Total			10.0000 grs.		100.000%

BORING No. 9

Sample No. 3

Greater than 5mm; less than 10mm.	= 0.6915	grs.=	6.915%
Greater than 2mm; less than 5mm.	= 1.1033	grs.=	11.033%
Greater than 1mm; less than 2mm.	= 0.5740	grs.=	5.740%
Greater than ½mm; less than 1mm.	= 0.4820	grs.=	4.820%
Greater than 1/20mm; less than ½mm.	= 3.9273	grs.=	39.273%
Less than 1/20mm	= 3.2219	grs.=	32.219%
Total	10.0000		100.000%

BORING No. 11

Sample No. 2

(Mineral grains and pipe scale fragments			
Greater than ½mm; less than 1mm.)	= 0.2270	grs.=	2.270%
Greater than 1/20mm; less than ½mm.	= 2.3300	grs.=	23.300%
Less than 1/20mm	= 7.4430	grs.=	74.430%
Total	10.0000	grs.	100.000%

Sample No. 3

Greater than 2mm; less than 5mm.	= 0.2587	grs.=	2.587%
Greater than 1mm; less than 2mm.	= 0.2171	grs.=	2.171%
Greater than ½mm; less than 1mm.	= 0.2600	grs.=	2.600%
Greater than 1/20mm; less than ½mm.	= 4.6640	grs.=	46.640%
Less than 1/20mm	= 4.6002	grs.=	46.002%
Total	10.0000	grs.	100.000%

BORING No. 13

Sample No. 2

(Shell fragments			
Greater than 2mm; less than 5mm.	= 0.0245	grs.=	0.245%
Greater than 1mm; less than 2mm.)	= 0.0069	grs.=	0.069%
Greater than ½mm; less than 1mm.	= 0.0140	grs.=	0.140%
Greater than 1/20mm; less than ½mm.	= 1.8263	grs.=	18.263%
Less than 1/20mm	= 8.1283	grs.=	81.283%
Total	10.0000	grs.	100.000%

Sample No. 3

(Shell fragments			
Greater than 5mm; less than 10mm.	= 0.1779	grs.=	1.779%
Greater than 2mm; less than 5mm.)	= 0.1952	grs.=	1.952%
(Chiefly shell fragments with a few mineral grains			
Greater than 1mm; less than 2mm.	= 0.1100	grs.=	1.100%
Greater than ½mm; less than 1mm.	= 0.1200	grs.=	1.200%
Greater than 1/20mm; less than ½mm.	= 2.9733	grs.=	29.733%
Less than 1/20mm.)	= 6.4236	grs.=	64.236%
Total	10.0000	grs.	100.000%

BORING No. 14

Sample No. 3

(One shell fragment and four pieces of pipe scale			
Greater than 2mm; less than 5mm.)	= 0.0496 grs.	=	0.496%
(Pipe scale fragments			
Greater than 1mm; less than 2mm.)	= 0.0269 grs.	=	0.269%
(Scale and mineral grains			
Greater than ½mm; less than 1mm.)	= 0.0172 grs.	=	0.172%
(Chiefly mineral grains			
Greater than 1/20mm; less than ½mm.	= 5.2247 grs.	=	52.247%
Less than 1/20mm.)	= 4.6816 grs.	=	46.816%
Total	10.0000 grs.		100.000%

Sample No. 4

(Chiefly fragments of rust (?) from core pipe			
Greater than ½mm; less than 1mm.)	= 0.1163 grs.	=	1.163%
Greater than 1/20mm; less than ½mm.	= 1.2820 grs.	=	12.820%
Less than 1/20mm.	= 8.6017 grs.	=	86.017%
Total	10.0000 grs.		100.000%

BORING No. 17

Sample No. 3

(Wood fragments			
Greater than ½mm.)	= 0.0905 grs.	=	0.905%
Greater than 1/20mm; less than ½mm.	= 0.8675 grs.	=	8.675%
Less than 1/20mm	= 9.0420 grs.	=	90.420%
Total	10.0000 grs.		100.000%

Sample No. 4

Greater than 5mm; less than 10mm.	= 0.3315 grs.	=	3.315%
Greater than 2mm; less than 5mm.	= 0.9030 grs.	=	9.030%
Greater than 1mm; less than 2mm.	= 0.9710 grs.	=	9.710%
Greater than ½mm; less than 1mm.	= 1.4346 grs.	=	14.346%
Greater than 1/20mm; less than ½mm.	= 6.2785 grs.	=	62.785%
Less than 1/20mm	= 0.0814 grs.	=	0.814%
Total	10.0000 grs.		100.000%

Sample No. 5

Greater than 1/20mm; less than ½mm.	= 4.2000 grs.	=	42.000%
Less than 1/20mm	= 5.8000 grs.	=	58.000%
Total	10.0000 grs.		100.000%

BORING No. 27

Sample No. 1

(Some wood fragments			
Greater than ½mm.)	= 0.0500 grs.	=	0.500%
Greater than 1/20mm; less than ½mm.	= 4.5890 grs.	=	45.890%
Less than 1/20mm	= 5.3610 grs.	=	53.610%
Total	10.0000 grs.		100.000%

BORING No. 29

Sample No. 3

Greater than	5mm;	less than	10mm.	= 1.5865 grs. =	15.865%
Greater than	2mm;	less than	5mm.	= 0.6690 grs. =	6.690%
Greater than	1mm;	less than	2mm.	= 0.3857 grs. =	3.857%
Greater than	½mm;	less than	1mm.	= 0.4357 grs. =	4.357%
Greater than	1/20mm;	less than	½mm.	= 3.3280 grs. =	33.280%
Less than	1/20mm			= 3.5951 grs. =	35.951%
Total				10.0000 grs.	100.000%

BORING No. 30

Sample No. 1

Greater than	5mm;	less than	10mm.	= 0.5327 grs. =	5.327%
Greater than	2mm;	less than	5mm.	= 0.9322 grs. =	9.322%
Greater than	1mm;	less than	2mm.	= 0.6945 grs. =	6.945%
Greater than	½mm;	less than	1mm.	= 0.9241 grs. =	9.241%
Greater than	1/20mm;	less than	½mm.	= 3.4650 grs. =	34.650%
Less than	1/20mm			= 3,4515 grs. =	34.515%
Total				10.0000 grs.	100.000%

BORING No. 31

Sample No. 3

(Chiefly shell fragments					
Greater than	½mm.)			= 0.2618 grs. =	2.618%
Greater than	1/20mm;	less than	½mm.	= 2.3520 grs. =	23.520%
Less than	1/20mm			= 7.3862 grs. =	73.862%
Total				10.0000 grs.	100.000%

Sample No. 4

(Shell fragments					
Greater than	1mm;	less than	2mm.)	= 0.0107 grs. =	0.107%
Greater than	½mm;	less than	1mm.	= 0.0167 grs. =	0.167%
Greater than	1/20mm;	less than	½mm.	= 0.9060 grs. =	9.060%
Less than	1/20mm			= 9.0666 grs. =	90.666%
Total				10.0000 grs.	100.000%

Sample No. 5

Greater than	½mm;			= 0.1942 grs. =	1.942%
Greater than	1/20mm;	less than	½mm.	= 3.0356 grs. =	30.356%
Less than	1/20mm			= 6.7702 grs. =	67.702%
Total				10.0000 grs.	100.000%

BORING No. 33

Sample No. 3

(Shell fragment					
Greater than	½mm.)			= 0.5235 grs. =	5.235%
Greater than	1/20mm;	less than	½mm.	= 2.1225 grs. =	21.225%
Less than	1/20mm			= 7.3540 grs. =	73.540%
Total				10.0000 grs.	100.000%

BORING No. 34

Sample No. 2

Greater than	1/20mm;	less than	½mm.	= 2.8729 grs. =	28.729%
Less than	1/20mm			= 7.1271 grs. =	71.271%
Total				10.0000 grs.	100.000%

Sample No. 4

Greater than	½mm;	less than	1mm.	= 0.0055 grs. =	0.055%
Greater than	1/20mm;	less than	½mm.	= 6.0332 grs. =	60.332%
Less	than 1/20mm			= 3.9613 grs. =	39.613%
Total				10.0000 grs.	100.000%

Sample No. 5

Greater than	½mm;	less than	1mm.	= 0.0065 grs. =	0.065%
Greater than	1/20mm;	less than	½mm.	= 3.2855 grs. =	32.855%
Less	than 1/20mm			= 6.7080 grs. =	67.080%
Total				10.0000 grs.	100.000%

BORING No. 35

Sample No. 3

Greater than	½mm;	less than	1mm.	= 0.0125 grs. =	0.125%
Greater than	1/20mm;	less than	½mm.	= 1.9990 grs. =	19.990%
Less	than 1/20mm			= 7.9885 grs. =	79.885%
Total				10.0000 grs.	100.000%

Sample No. 4

Greater than	5mm;	less than	10mm.	= 0.4635 grs. =	4.635%
Greater than	2mm;	less than	5mm.	= 0.2350 grs. =	2.350%
Greater than	1mm;	less than	2mm.	= 0.0820 grs. =	0.820%
Greater than	½mm;	less than	1mm.	= 0.0300 grs. =	0.300%
Greater than	1/20mm;	less than	½mm.	= 1.5500 grs. =	15.500%
Less	than 1/20mm			= 7.6395 grs. =	76.395%
Total				10.0000 grs.	100.000%

Sample No. 5

(Chiefly pipe scale					
Greater than	1mm;	less than	2mm.)	= 0.0080 grs. =	0.080%
(Mineral grains and pipe scale					
Greater than	½mm;	less than	1mm.)	= 0.0130 grs. =	0.130%
Greater than	1/20mm;	less than	½mm.	= 2.7040 grs. =	27.040%
Less	than 1/20mm.			= 7.2750 grs. =	72.750%
Total				10.0000 grs.	100.000%

Sample No. 6

Greater than	2mm;	less than	5mm.	= 0.1312 grs. =	1.312%
Greater than	1mm;	less than	2mm.	= 0.3012 grs. =	3.012%
Greater than	½mm;	less than	1mm.	= 1.6932 grs. =	16.932%
Greater than	1/20mm;	less than	½mm.	= 7.5692 grs. =	75.692%
Less	than 1/20mm			= 0.3052 grs. =	3.052%
Total				10.0000 grs.	100.000%

BORING No. 36

Sample No. 3

Greater than	1mm;	less than	2mm.	= 0.0110 grs. =	0.110%
Greater than	½mm;	less than	1mm.	= 0.0730 grs. =	0.730%
Greater than	1/20mm;	less than	½mm.	= 7.3372 grs. =	73.372%
Less	than 1/20mm;			= 2.5788 grs. =	25.788%
Total				10.0000 grs.	100.000%

BORING No. 37

Sample No. 3

(Shell fragment			
Greater than 5mm; less than 10mm.)	= 0.0752 grs.	=	0.752%
Greater than 2mm; less than 5mm.	= 0.6465 grs.	=	6.465%
Greater than 1mm; less than 2mm.	= 1.5032 grs.	=	15.032%
Greater than ½mm; less than 1mm.	= 2.8782 grs.	=	28.782%
Greater than 1/20mm; less than ½mm.	= 2.6505 grs.	=	26.505%
Less than 1/20mm.	= 2.2464 grs.	=	22.464%
Total	10.0000 grs.		100.000%

Sample No. 4

Greater than 1/20mm; less than ½mm.	= 1.7575 grs.	=	17.575%
Less than 1/20mm	= 8.2425 grs.	=	82.425%
Total	10.0000 grs.		100.000%

BORING No. 38

Sample No. 2

Greater than ½mm; less than 1mm.	= 0.0200 grs.	=	0.200%
Greater than 1/20mm; less than ½mm.	= 1.7000 grs.	=	17.000%
Less than 1/20mm	= 8.2800 grs.	=	82.800%
Total	10.0000 grs.		100.000%

Sample No. 3

Greater than 1/20mm; less than ½mm.	= 7.4387 grs.	=	74.387%
Less than 1/20mm	= 2.5613 grs.	=	25.613%
Total	10.0000 grs.		100.000%

Sample No. 4

Greater than 1/20mm; less than ½mm.	= 1.1679 grs.	=	11.679%
Less than 1/20mm	= 8.8321 grs.	=	88.321%
Total	10.0000 grs.		100.000%

BORING No. 41

Sample No. 1

(Shell fragments			
Greater than 10mm;	= 0.2245 grs.	=	2.245%
Greater than 5mm; less than 10mm.)	= 0.0123 grs.	=	0.123%
(Chiefly shell fragments			
Greater than 2mm; less than 5mm.)	= 0.2195 grs.	=	2.195%
(Shell fragments and mineral grains			
Greater than 1mm; less than 2mm.)	= 0.0833 grs.	=	0.833%
(Chiefly mineral grains with some few shell fragments			
Greater than ½mm; less than 1mm.)	= 0.1790 grs.	=	1.790%
(Mineral grains			
Greater than 1/20mm; less than ½mm.	= 3.2587 grs.	=	32.587%
Less than 1/20mm.)	= 6.0227 grs.	=	60.227%
Total	10.0000 grs.		100.000%

Sample No. 2

(Chiefly mineral grains and some pipe scale			
Greater than ½mm; less than 1mm.)	= 0.0440 grs.	=	0.440%
Greater than 1/20mm; less than ½mm.	= 5.9947 grs.	=	59.947%
Less than 1/20mm	= 3.9613 grs.	=	39.613%
Total	10.0000		100.000%

TIDES

1. **Mean Sea Level.** Tides have been observed uninterruptedly since 1897 by means of a United States Coast and Geodetic Survey automatic tide gauge at the Presidio of San Francisco. All of the observations were reduced to a staff, the zero of which was carefully connected by spirit levels with adjacent bench marks. During the 26 years (1897–1924) of observations, mean sea level was found to be 8.555 on the staff. Sea level was lowest in 1898 with a value of 8.30 feet and highest in December, 1914, with a value of 9.16 feet.

Sea level is lowest in the spring, with a minimum generally in April or May, and highest in the fall with a maximum generally in September or October.

2. **Standard Sea Level.** Considerable variation in mean sea level exists even when determined from a number of years of observations. Because of this bothersome condition, the United States Coast and Geodetic Survey has adopted a standard sea level datum at the Presidio of 8.519 feet on the tide staff. This plane is based upon 16 years of continuous observations from 1898 to 1913.

3. **Mean Lower Low Water.** As determined by the mean of two overlapping 19-year periods, 1898 to 1917 and 1905 to 1924, the elevation of mean lower low water is 5.50 on the Presidio tide staff.

4. **Standard Lower Low Water.** This is the datum plane for the United States Coast and Geodetic Survey charts and tide tables on the Pacific coast. Its elevation on the Presidio tide staff is 5.55. Some ambiguity here arises as this datum is usually referred to as mean lower low water. Since the actual mean lower low varies continually as new observations are made, it was necessary to establish a stationary of standard mean lower low water.

All of our observations and studies, and consequently all elevations and depths given in this report, are based upon this standard lower low water, also called mean lower low water, elevation 5.55 on the Presidio tide staff.

5. **Meteorological and Seismological Effects.** The range of the tide at any given place varies almost constantly; it is exceptional to find consecutive ranges equal. Meteorological conditions such as winds, sudden barometric changes and storms have a marked effect. A strong wind can so retard an ebb tide that it will not have completely run out before the next flood comes in. The prevailing westerly winds of the San Francisco Bay region are quite conducive to this effect.

Seismic disturbances also effect the range but not to a great extent in this region, as the fault shifts are almost entirely horizontal.

6. **Storm Tides.** The unusually high and low tides caused by meteorological conditions are called "storm tides" and their corresponding ranges, the "storm ranges."

7. **Unusual or "Freak" Tides.** There are various causes of uuusual tides occurring at different intervals. Consequently there is a wide range of combinations in which these conditions can occur. They may come separately, or all together in combination with a storm and high wind.

The highest yearly average of high tides occurred in 1914. This average H. H. W. was 6.89 feet above M. L. L. W., and was principally affected by the extreme high tides of the month of December which on the sixteenth and seventeenth went up to 7.9. It is reported that during that month the Key Route Ferry steamers were obliged to shorten their flag poles in order to clear the shed on the Key Route Pier.

The highest tide on record occurred November 18, 1918, its height being 8.2 feet above M. L. L. W. The lowest tide occurred December 25, 1912, and December 9, 1923, when lower low water dropped to –2.3.

TABLE No. 51. SUMMARY OF TIDAL DATA

Height relations	Average feet from M. L. L.
Storm high water	6.62
Storm low water	—1.18
Highest observed high water (November 18, 1918)	8.25
Lowest observed low water (December 25, 1912 and December 9, 1923)	—2.25
Greatest possible range=8.25+ —.2.25 and has probably never actually occurred	10.50
Mean range	3.93
Highest yearly average of highest tides (1914)	6.89
Lowest yearly average of lowest tides (1912)	—1.59

Time relations	Time intervals	Average in hours
High water interval	Moon's transit to next high tide	11.67
Low water interval	Moon's transit to next low tide	4.97
Duration of rise	Low tide to following high tide	6.70
Duration of fall	High tide to following low tide	5.72
Phase age	Full or new moon to spring tides—quarters to neap tides	4.90
Parallax age	Moon in apogee to apogean tides—moon in perigee to perigean tides	47.80
Diurnal age	Moon's declination to resulting tide	15.50

Standard sea level is at elevation 8.519 on the Presidio tide staff.
Standard mean lower low water, elevation 5.55 Presidio tide staff.
Relation between standard sea level and mean lower low water=8.52—5.55=2.97 feet.

W.P.Ry.	C.P.Ry. Ext. Low Water S.F. Bay	State of California previous to 1885	U.S.C.&G.S. ⊛ Standard Mean Lower Low Water	Calif Debris Comm.	U.S.E.D.	Sacramento	U.S.G.S.& State of Calif (Mean Sea Level)	Berkeley	S.P.R.R. (High Water S.F. Bay)	Oakland Alameda County San Leandro	Alameda	U.S.C.&G.S. Land Elev.	San Francisco
13.34	12.20	11.69	11.43	10.97	10.93	7.84	7.37	5.79	5.73	5.40	5.12	3.81	0.00
9.53	8.39	7.88	7.62	7.16	7.12	4.03	3.56	1.98	1.92	1.59	1.31	0.00	
8.22	7.08	6.57	6.31	5.85	5.81	2.72	2.25	0.67	0.61	0.28	0.00		
7.94	6.80	6.29	6.03	5.57	5.53	2.44	1.97	0.39	0.33	0.00			
7.61	6.47	5.96	5.70	5.24	5.20	2.11	1.64	0.06	0.00				
7.55	6.41	5.90	5.64	5.18	5.14	2.05	1.58	0.00					
5.97	4.83	4.32	4.06	3.60	3.56	0.47	0.00	EXAMPLE					
5.50	4.36	3.85	3.59	3.13	3.09	0.00		Elev. 30.00 Soc'to = 30.00 + 4.36 = Elev. 34.36 C.P.Ry.					
2.41	1.27	0.76	0.50	0.04	0.00								
2.37	1.23	0.72	0.46	0.00									
1.91	0.77	0.26	0.00										
1.65	0.51	0.00		⊛ Datum used in this report.									
1.14	0.00												
0.00													

Relation Between Elevations Various Datum Planes

PLATE No. 25

CURRENTS

1. **General.** The currents in tidal waters may be divided into two classes, suggested by their causes, as tidal and nontidal currents.

Tidal currents are the horizontal components of the tidal motion, and are consequently intimately related to the tides, being brought about by the tide producing forces of sun and moon. Like the tides, they are therefore periodic.

Nontidal currents are brought about by causes independent of the tides, such as winds, fresh water run-off, differences in density and temperature and differences in head where a natural constriction separates tidal bodies of water. Thus it is seen that nontidal currents are not periodic *and consequently not predictable.*

For this reason published current tables do not include nontidal currents, and actually observed currents often vary by as much as 20 or 25 per cent from the predicted current velocity.

It may be well here to define some of the most frequently used terms relative to tidal currents. The "flood" current is that current which sets inland or up stream. The "set" of a current is its direction of flow. The "ebb" current is that current whose set is seaward or down stream. "Slack water" is the transition from ebb to flood or from flood to ebb. "Strength of current" is the term used to denote maximum velocity during flood or ebb. The terms "ebb tide" and "flood tide" are often used to denote ebb and flood currents. Although strictly incorrect, their use is so universal that little confusion results. The distinction between ebb and flood currents and rising and falling tides should be borne in mind when discussing tides or currents.

2. **Time Relations of Currents to Tides.** In San Francisco Bay, the tides are of the so called "stationary wave" type; c. g., the entire area is rising or falling at the same time. Theoretically, with this type of wave, slack water comes at times of high or low tide with strength of current coming half way between. Actually, the currents consistently lag behind the tides by varying lengths of time. This is caused by inertia and the more or less permanent set of the nontidal currents.

The relation between time of slack water or strength of current and time of tide is far from constant, so that persons interested in the exact times of slack water or strength of current should provide themselves with current tables published by the United States Coast and Geodetic Survey.

Mean values are given below for purposes of estimation:

At the entrance, which is the reference station upon which all published tide and current tables are based, low water slack occurs two hours after low water and high water slack occurs 1¾ hours after high water (p. 65, Tides and Currents in San Francisco Bay).

Strength of flood occurs about 0.47 of the duration of the flood in hours after low water slack.

Strength of ebb occurs about 0.45 of the duration of the ebb after high water slack (pp. 66 and 67, Tides and Currents in San Francisco Bay).

In the vicinity of Mission street, Goat Island and the Alameda Mole, low water slack occurs about one-half hour before low water slack at the entrance, and high water slack occurs about 1½ hours before high water slack at the entrance (pp. 90 and 101, Tides and Currents in San Francisco Bay).

3. **Velocities in a Vertical Plane.** Velocities have been measured at various locations over San Francisco Bay and at depths of 0.8, 0.5, 0.2 of the total depth, and just far enough below the surface to eliminate wave action, by the Coast and Geodetic Survey at various times since 1856. The results have been tabulated on pages 72 et seq. of the publication "Tides and Currents in San Francisco Bay." (United States Coast and Geodetic Survey.)

In order to show the current velocities to be expected at any depth throughout the area covered by our explorations, the results of the twelve stations in and nearest to this area are copied in Table No. 52.

The depths below mean lower low water are given in feet and the corresponding velocities in knots. These depths in fractions of total depth and the velocities in per cent of the surface velocity were computed and tabulated.

With these fractional depths as ordinates, and the velocities in per cent as abscissae, the results of Table No. 52 were plotted on Plate No. 26, and a mean curve drawn.

With any given surface velocity, and from the abscissae to the curve, the corresponding velocities at all depths can be computed. Since force is a function of

the velocity, and if the Y axis is taken to represent the upstream face of a pier, this curve becomes the force diagram of the dynamic forces of the moving water against the side of the pier.

TABLE No. 52. VELOCITIES AT VARIOUS DEPTHS IN THE VICINITY OF THE SAN FRANCISCO BAY BORINGS

(Copied from the U. S. C. & G. S. publication entitled, "Tides and Currents in San Francisco Bay," Tables Nos. 42 and 43.)

Station Number	Depth below surface		Maximum ebb velocity		Station number	Depth below surface		Maximum ebb velocity	
	Feet	Fraction of total	Knots	Fraction of surface velocity		Feet	Fraction of total	Knots	Fraction of surface velocity
38	7	0.27	0.87	1.00	57	7	0.10	0.94	1.00
	8	.30	.71	.82		13	.20	.61	.65
	20	.50	.70	.80		33	.50	.77	.82
	31	.80	.76	.87		53	.80	.71	.76
39	7	.10	1.95	1.00	59	7	.09	2.62	1.00
	15	.20	1.98	1.02		16	.20	2.36	.90
	38	.50	1.76	.90		39	.50	2.10	.80
	61	.80	1.53	.79		62	.80	1.59	.61
41	7	.07	2.09	1.00	61	7	.12	2.05	1.00
	20	.20	2.13	1.02		11	.20	2.24	1.09
	50	.50	1.87	.90		28	.50	1.73	.84
	80	.80	1.53	.73		46	.80	1.14	.56
43	7	.05	2.08	1.00	63	7	.13	1.39	1.00
	29	.20	1.90	.91		10	.20	1.03	.74
	72	.50	1.78	.86		26	.50	1.07	.77
	115	.80	1.61	.77		42	.80	.95	.68
48	7	.18	1.14	1.00	69	7	.16	1.97	1.00
	8	.21	1.14	1.00		9	.20	1.84	.93
	20	.50	1.00	.97		23	.50	1.60	.81
	31	.80	.80	.70		36	.80	1.24	.63
54	7	.23	1.58	1.00	70	7	.16	1.38	1.00
	6	.20	1.46	.91		9	.20	1.58	1.14
	15	.50	1.24	.79		21	.50	1.43	1.04
	24	.80	.96	.61		34	.80	1.18	.86

One knot=1.1528 statute miles=6086.7 feet.

4. **Surface Velocities.** The average velocities of strength of flood and ebb currents are as follows: Goat Island line 1.6 and 2.1 miles per hour, respectively, and for the other lines, 1.8 and 2.3 miles per hour. (p. 72, Tides and Currents in San Francisco Bay.)

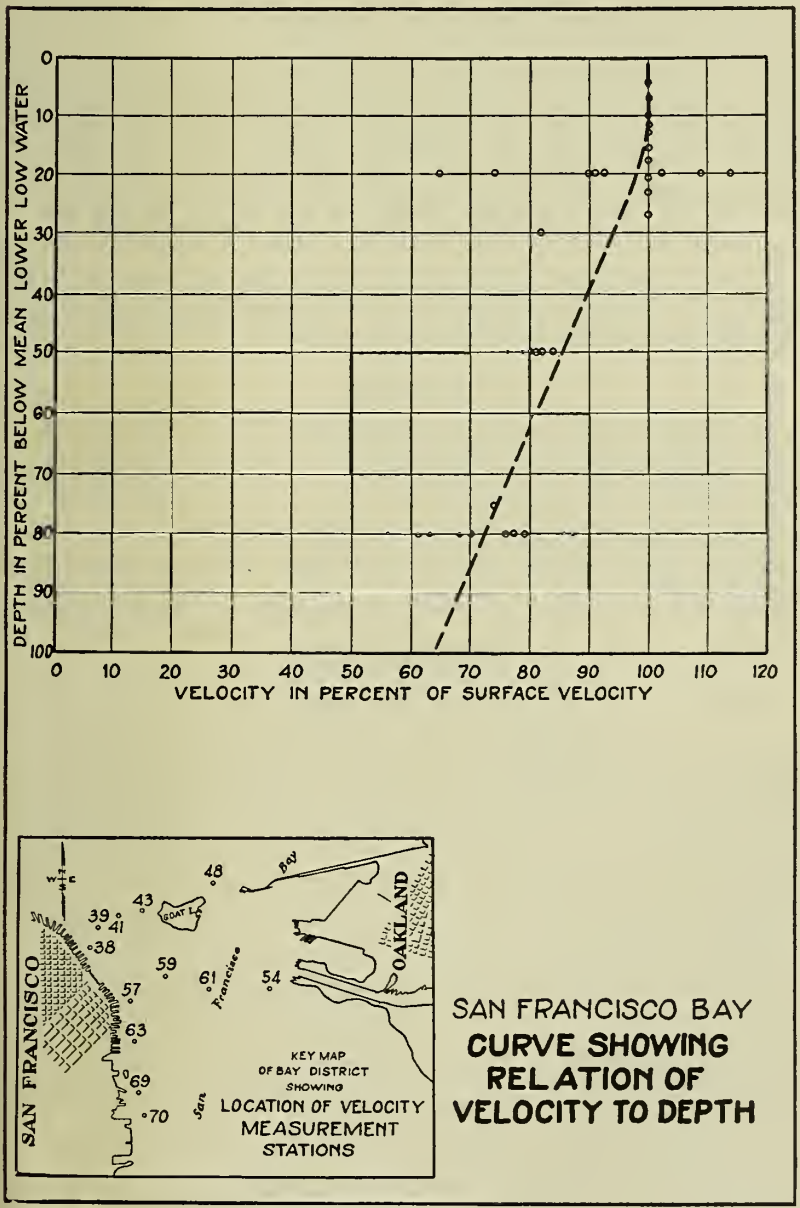

DEPTH IN PERCENT BELOW MEAN LOWER LOW WATER
0
10
20
30
40
50
60
70
80
90
100
0 10 20 30 40 50 60 70 80 90 100 110 120
VELOCITY IN PERCENT OF SURFACE VELOCITY
SAN FRANCISCO
OAKLAND
48
43
39
41
38
59
61
54
57
63
69
70
BOAT L.
KEY MAP
OF BAY DISTRICT
SHOWING
LOCATION OF VELOCITY
MEASUREMENT
STATIONS
SAN FRANCISCO BAY
CURVE SHOWING
RELATION OF
VELOCITY TO DEPTH

PLATE No. 26

It can be shown mathematically that the mean velocity throughout a tidal cycle is 0.64 of the strength of current.

The maximum predicted current for this area in 1930 is 4.7 miles per hour to occur in the afternoon of January 14th and in the morning of July 26th. The range of this tide on July 26th is to be 8.3 feet and the duration is to be 7 hours, 25 minutes.

In general, velocity of current varies directly as the range of tide and inversely as the duration. This is far from being an accurate relationship but will serve as a means of arriving at an approximate value of the maximum current to be expected. We have shown that actual velocities can exceed predicted velocities by as much as 20 or 25 per cent. Whenever we have had occasion to measure velocities, we have found them to exceed the predicted velocity by about 20 per cent. We have also shown that the maximum range to be expected is 10.5 feet.

If we hold the duration constant—assume it at its mean value, and express the above assumptions in the form of an equation we obtain: $\frac{4.7 \times 10.5 \times 1.25}{8.3} = 7.5$ miles per hour as the maximum possible current velocity that can occur. It is highly improbable that this velocity will ever be attained as it is based upon the assumption of all extreme conditions occurring at once. However, designs based upon this figure (7.5) will most likely be on the side of safety.

SUMMARY

Average strength of flood current, Goat Island line	1.6 miles per hour
Average strength of ebb current, Goat Island line	2.1 miles per hour
Average strength of flood current, other lines	1.8 miles per hour
Average strength of ebb current, other lines	2.3 miles per hour

Average current velocity, 64 per cent of strength of current.

Maximum possible theoretical current, 7.5 miles per hour.

Maximum velocity actually observed while taking borings, 6 miles per hour, February 12, 1930.

Maximum predicted velocity for 1930, 4.7 miles per hour, 3.40 a.m., July 26th.

WEATHER DATA

1. **Temperature.** Maximum temperature 101.2.
Minimum temperature 29.0.

2. **Winds.** Summer winds may be grouped as follows: west to northwest, 75 per cent; north to northeast, 4 per cent; east to southeast, 3 per cent; south to southwest, 3 per cent and calms, 15 per cent.

Winter winds—west to northwest, 30 per cent; north to northeast, 18 per cent; east to southeast, 17 per cent; south to southwest, 22 per cent; and calms, 13 per cent.

The highest wind velocity recorded from the northwest at Point Reyes Light, California, was 110 miles an hour.

The highest wind velocity recorded in San Francisco was 64 miles au hour from the northeast.

3. **Fog.** In winter, morning fogs, or, as they are commonly called "tule" fogs frequently occur. These are thick, low-lying banks of condensed vapor formed by radiation. These fogs move seaward. The average number of foggy days is 24 per year.

During the months of June, July and August a sea fog appears from the Golden Gate usually about 1 p.m. and covers the whole sky by 3 p.m. The average depth of the fog layer is 1700 feet. During these three months 50 per cent of the possible sunshine is excluded between 3 p.m. and 7 p.m.

There is also a curtailment of sunshine from May to September, inclusive, in the early morning between 7 a.m. and 9 a.m.

A phenomenon characteristic of San Francisco Bay is a low-lying haze quite prevalent in the early summer months which greatly obstructs vision, making it difficult to distinguish landmarks on the opposite side of the bay. Under certain atmospheric conditions, usually in the early morning when there is no wind blowing, a dense black pall of smoke overhangs the city making it impossible to distinguish points beyond the water's edge. This condition prevails ordinarily until about 9.30 a.m. when a light wind usually clears the atmosphere.

Plate No. 27

PASSENGER FERRY LINES AND SUGGESTED BRIDGE LOCATIONS

PLATE 27

SAN FRANCISCO BAY AREA

SHOWING

PRESENT SAN FRANCISCO — EAST BAY

PASSENGER FERRY LINES

FIVE SUGGESTED BRIDGE LOCATIONS

AND

ORIGIN-DESTINATION OF PASSENGER TRAFFIC

DECEMBER, 12, 1929.

INDICATES TRAFFIC CENTERS

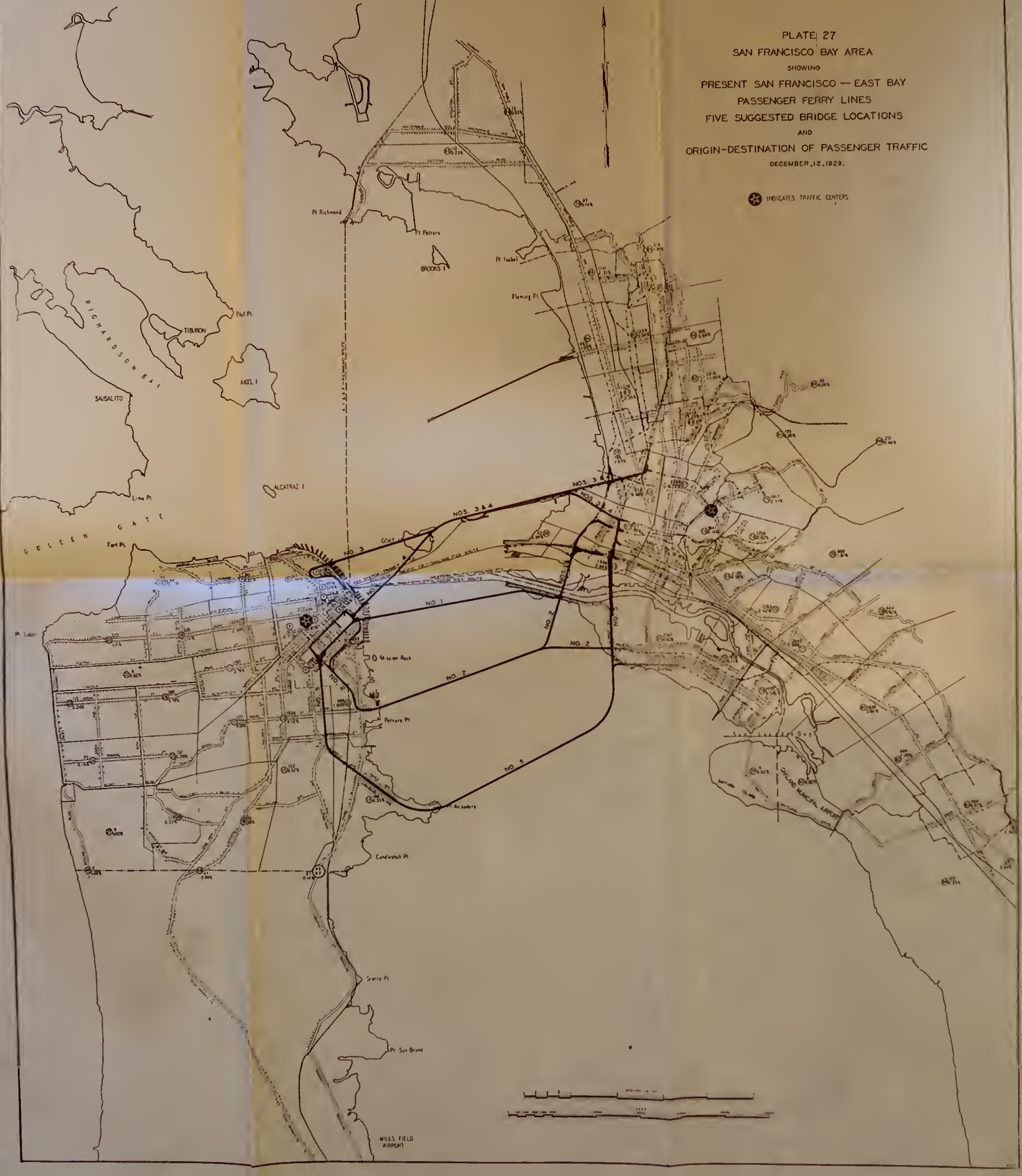


Plate No. 27

PASSENGER FERRY LINES AND SUGGESTED BRIDGE LOCATIONS

PLATE 27

SAN FRANCISCO BAY AREA

SHOWING

PRESENT SAN FRANCISCO — EAST BAY

PASSENGER FERRY LINES

FIVE SUGGESTED BRIDGE LOCATIONS

AND

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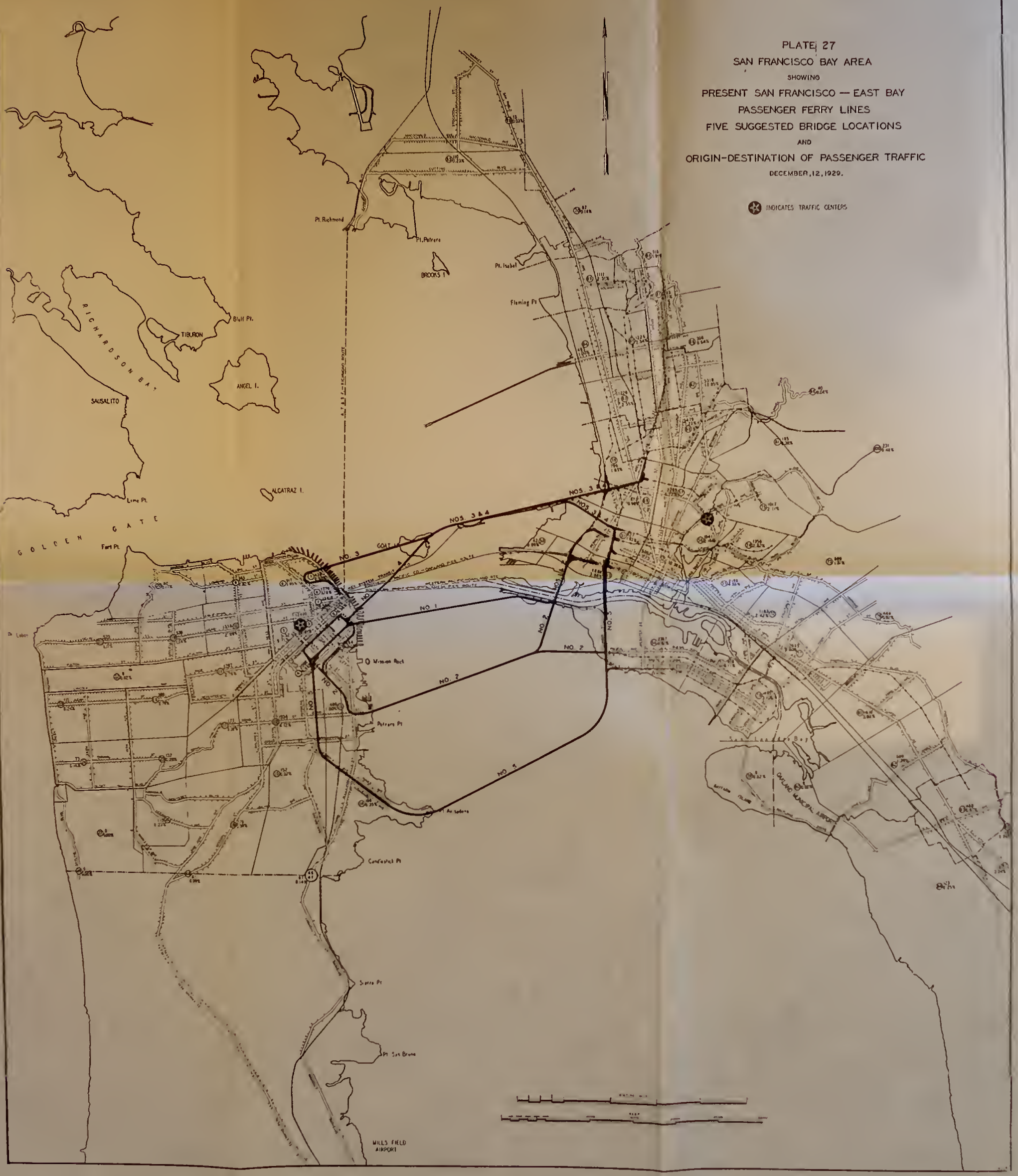


Plate No. 29

DIAGRAM OF PASSENGER FERRY TRAFFIC

PLATE 29

DIAGRAM

OF SAN FRANCISCO — EAST BAY

PASSENGER FERRY TRAFFIC

BY PRESENT ROUTES

DECEMBER, 12, 1929.

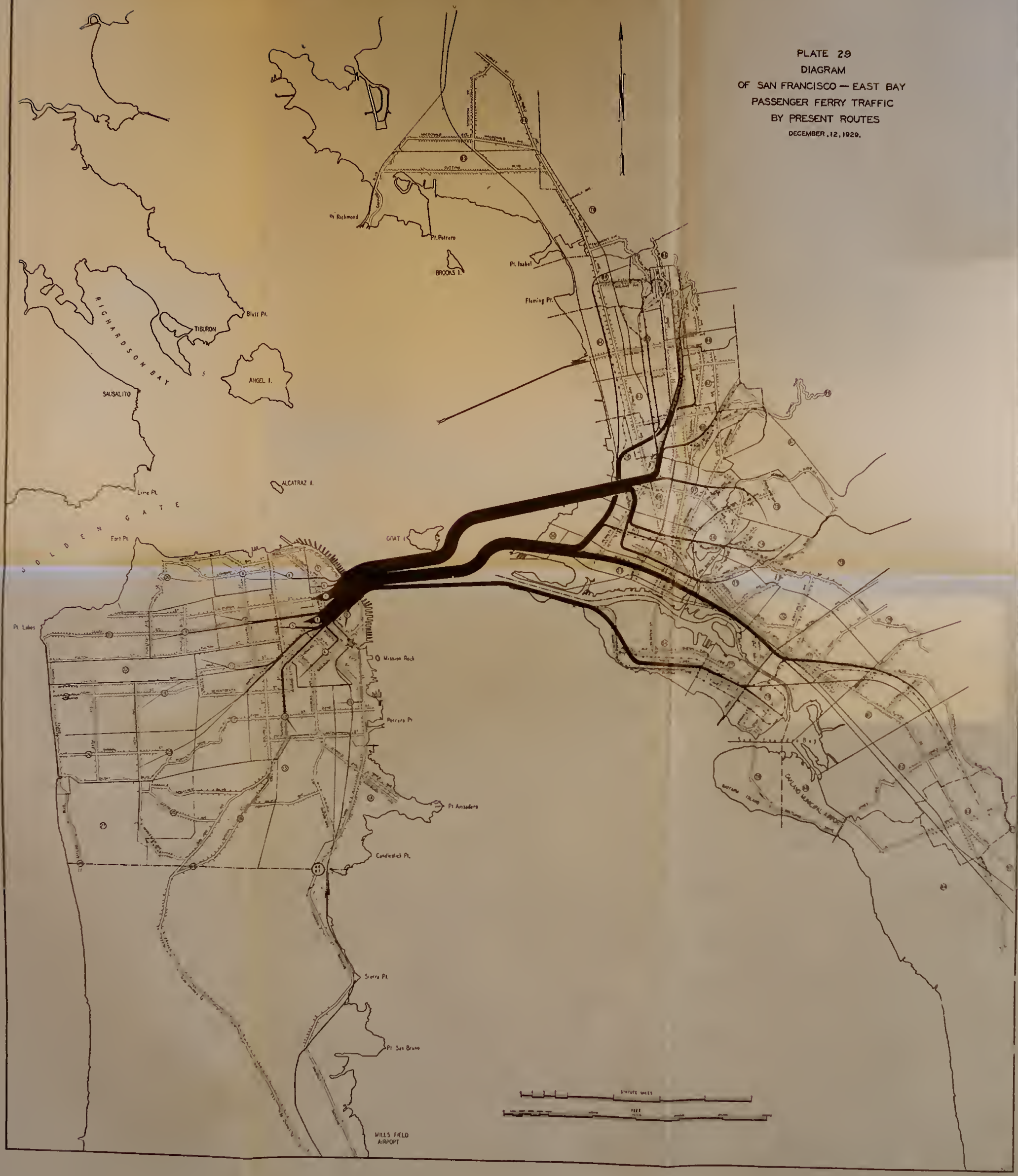


Plate No. 30

DIAGRAM OF PASSENGER FERRY TRAFFIC ROUTES BY BRIDGE LOCATION No. 1

PLATE 30

DIAGRAM

OF SAN FRANCISCO — EAST BAY

PASSENGER FERRY TRAFFIC

ROUTED BY BRIDGE LOCATION 1

DECEMBER, 12, 1929.

Pt Richmond

Pt. Potrero

BROOKS I.

Pt. Isabel

Fleming Pt.

RICHARDSON BAY

Bluff Pt.

TIBURON

ANGEL I.

SAUSALITO

ALCATRAZ I.

Lime Pt.

GOLDEN GATE

Fort Pt

GOAT I.

Pt Lobos

Mission Rock

Potrero Pt

Pt. Avisadero

Candlestick Pt.

Sierra Pt.

Pt. San Bruno

MILLS FIELD AIRPORT

San Leandro Bay

BAY FARM ISLAND

OAKLAND MUNICIPAL AIRPORT

STATUTE MILES

FEET

Plate No. 31

DIAGRAM OF PASSENGER FERRY TRAFFIC ROUTES BY BRIDGE LOCATION No. 4

PLATE 31

DIAGRAM

OF SAN FRANCISCO — EAST BAY

PASSENGER FERRY TRAFFIC

ROUTED BY BRIDGE LOCATION 4

DECEMBER, 12, 1929.

Pt Richmond

Pt. Potrero

BROOKS I.

Pt. Isabel

Fleming Pt.

RICHARDSON BAY

Bluff Pt.

TIBURON

ANGEL I

SAUSALITO

Lime Pt.

ALCATRAZ I.

GOLDEN GATE

Fort Pt.

GOAT I.

Pt. Lobos

Mission Rock

Potrero Pt.

Pt. Avisadero

Candlestick Pt.

Sierra Pt.

Pt. San Bruno

MILLS FIELD AIRPORT

San Leandro Bay

BAYFARM ISLAND

OAKLAND MUNICIPAL AIRPORT

STATUTE MILES

FEET

Plate No. 32

DIAGRAM OF VEHICULAR FERRY TRAFFIC EAST BAY–SAN FRANCISCO

PLATE 32

DIAGRAM

OF SAN FRANCISCO — EAST BAY

VEHICULAR FERRY TRAFFIC

BY PRESENT ROUTES

DECEMBER, 17, 1929.

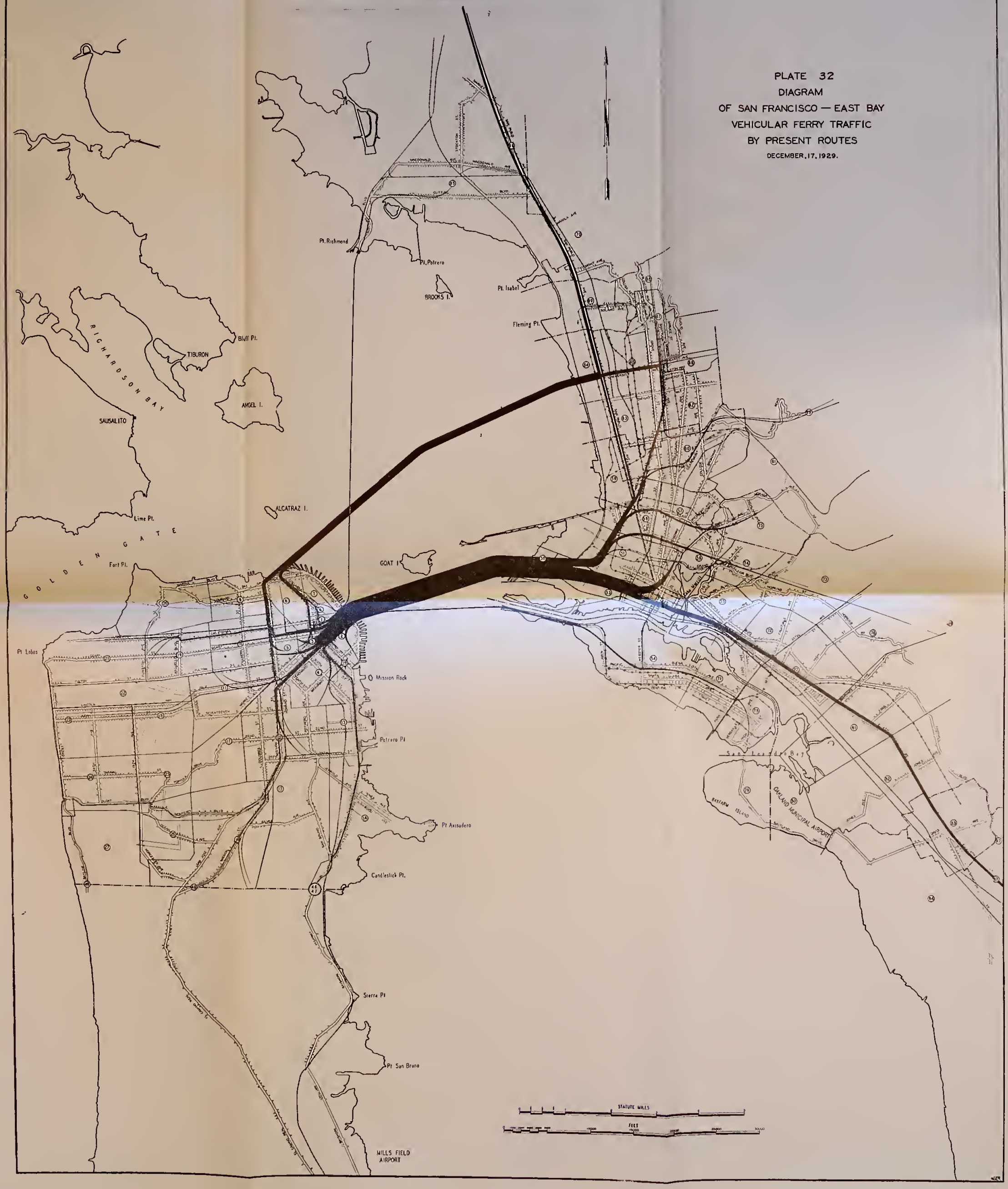


Plate No. 33

DIAGRAM OF VEHICULAR FERRY TRAFFIC ROUTES BY BRIDGE LOCATION No. 1

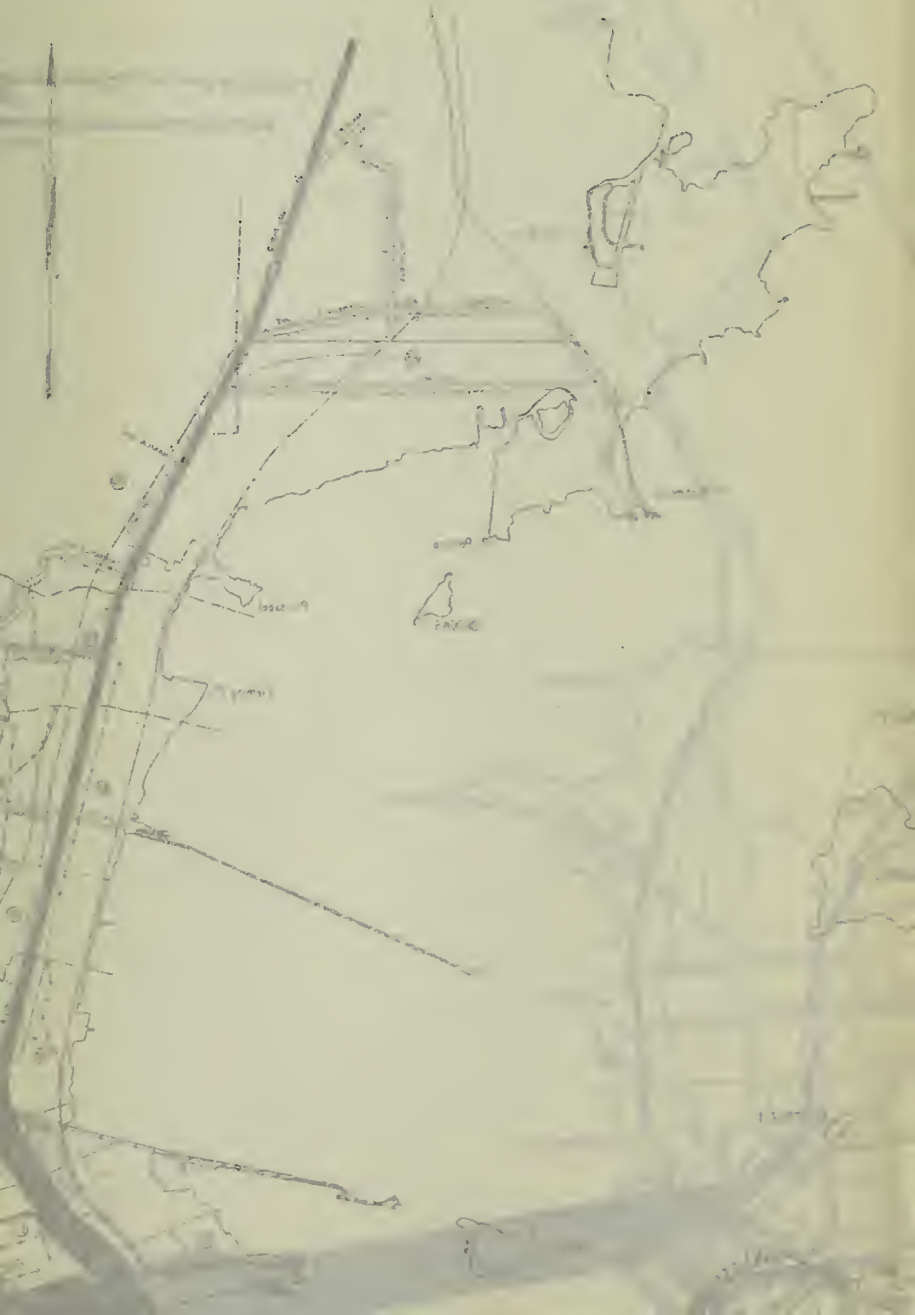


PLATE 33

DIAGRAM

OF SAN FRANCISCO — EAST BAY

VEHICULAR FERRY TRAFFIC

ROUTED BY BRIDGE LOCATION 1

DECEMBER 17, 1929.

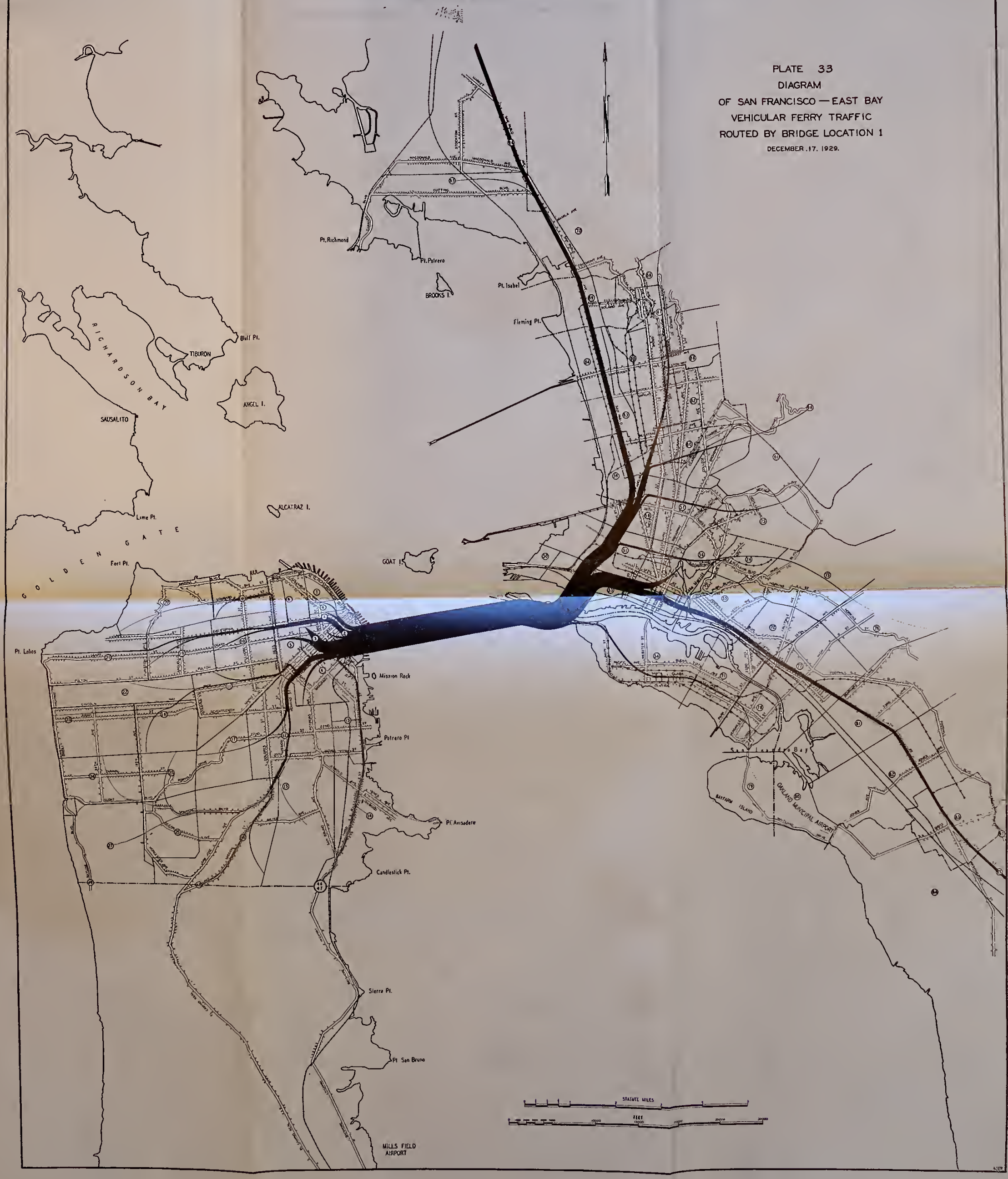


Plate No. 34

DIAGRAM OF VEHICULAR FERRY TRAFFIC BY BRIDGE LOCATION No. 4

PLATE 34

DIAGRAM

OF SAN FRANCISCO — EAST BAY

VEHICULAR FERRY TRAFFIC

ROUTED BY BRIDGE LOCATION 4

DECEMBER, 17, 1929.

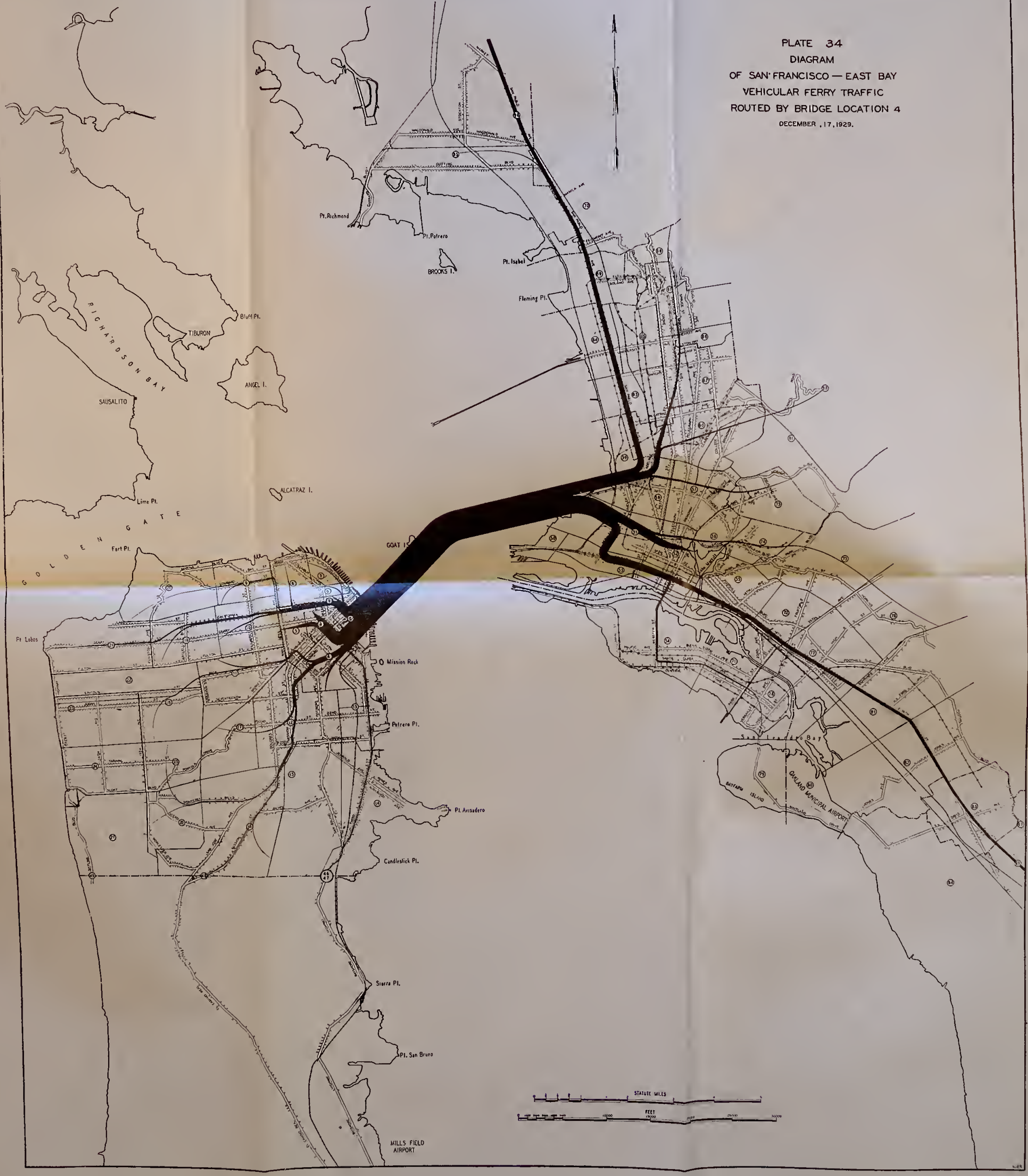


Plate No. 35

SAN FRANCISCO AND VICINITY, APPROXIMATE BOUNDARIES OF LOW LEVEL AREAS

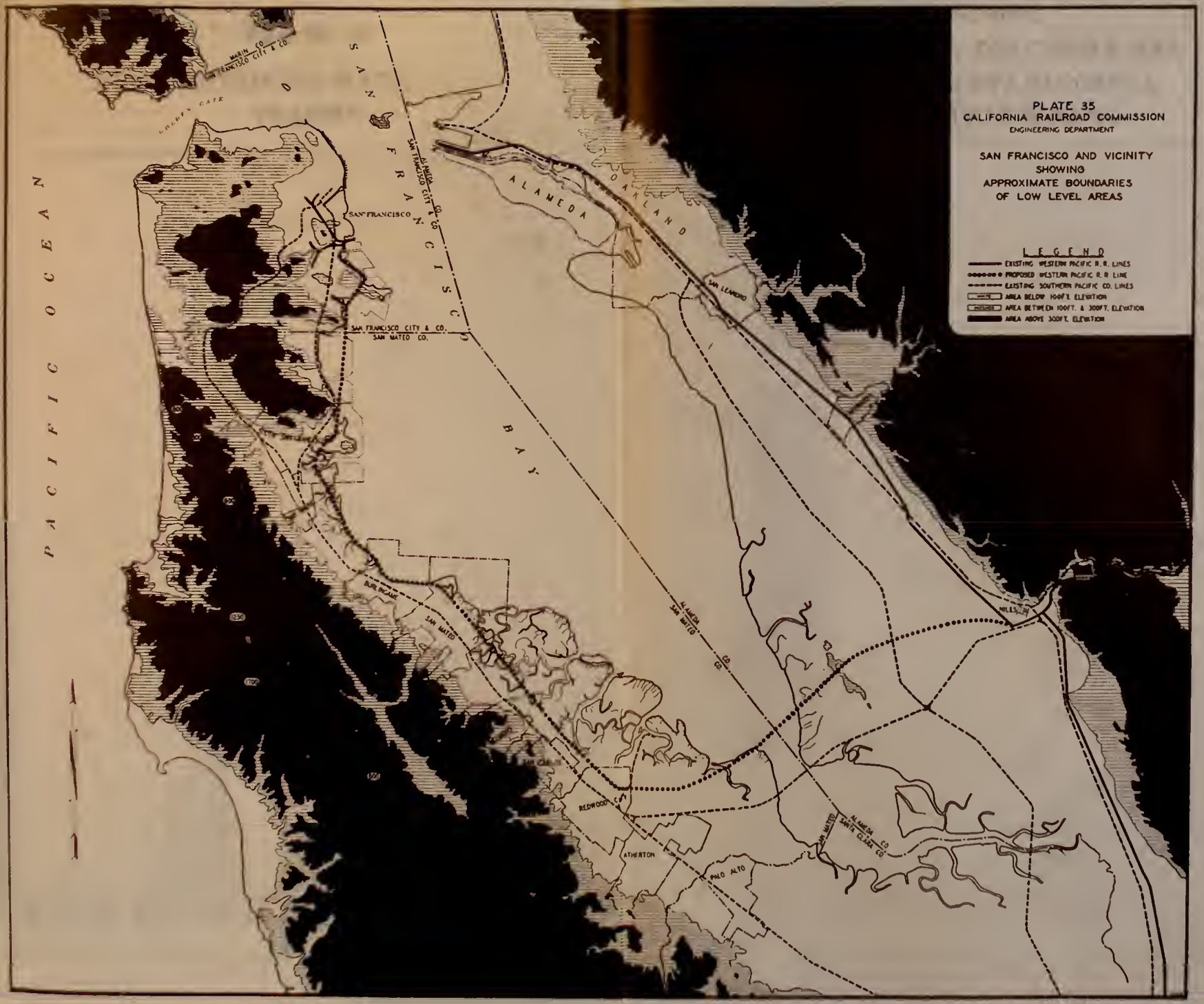
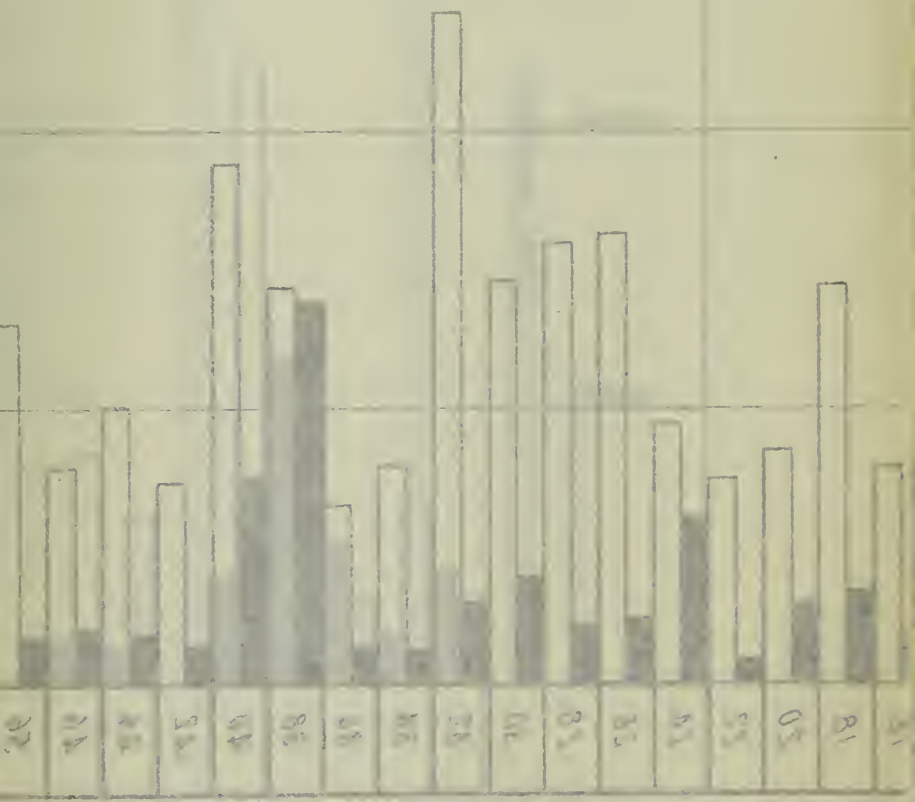


PLATE 35
CALIFORNIA RAILROAD COMMISSION
ENGINEERING DEPARTMENT
SAN FRANCISCO AND VICINITY
SHOWING
APPROXIMATE BOUNDARIES
OF LOW LEVEL AREAS
LEGEND
EXISTING WESTERN PACIFIC R. R. LINES
PROPOSED WESTERN PACIFIC R. R. LINE
EXISTING SOUTHERN PACIFIC CO. LINES
AREA BELOW 100FT. ELEVATION
AREA BETWEEN 100FT. & 300FT. ELEVATION
AREA ABOVE 300FT. ELEVATION
PACIFIC OCEAN
SAN FRANCISCO BAY
GOLDEN GATE
MARIN CO.
SAN FRANCISCO CITY & CO.
SAN FRANCISCO
ALAMEDA
OAKLAND
SAN LEANDRO
SAN FRANCISCO CITY & CO.
SAN MATEO CO.
BURLINGAME
SAN MATEO
ALAMEDA
SAN MATEO CO.
HAYWARD
REDWOOD CITY
ATHERTON
PALO ALTO
SAN MATEO
ALAMEDA CO.
SANTA CLARA CO.

Plate No. 36

DISTRIBUTION OF WATER BORNE TRAFFIC



Piers North of Market St.

Piers South of Market St.

Zone No. 5
" " 4
" " 3
" " 2
" " 1

HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION

CHART SHOWING DISTRIBUTION OF WATER BORNE TRAFFIC

Vessels Arriving ----------
Net Tonnage ----------

PLATE Nº36

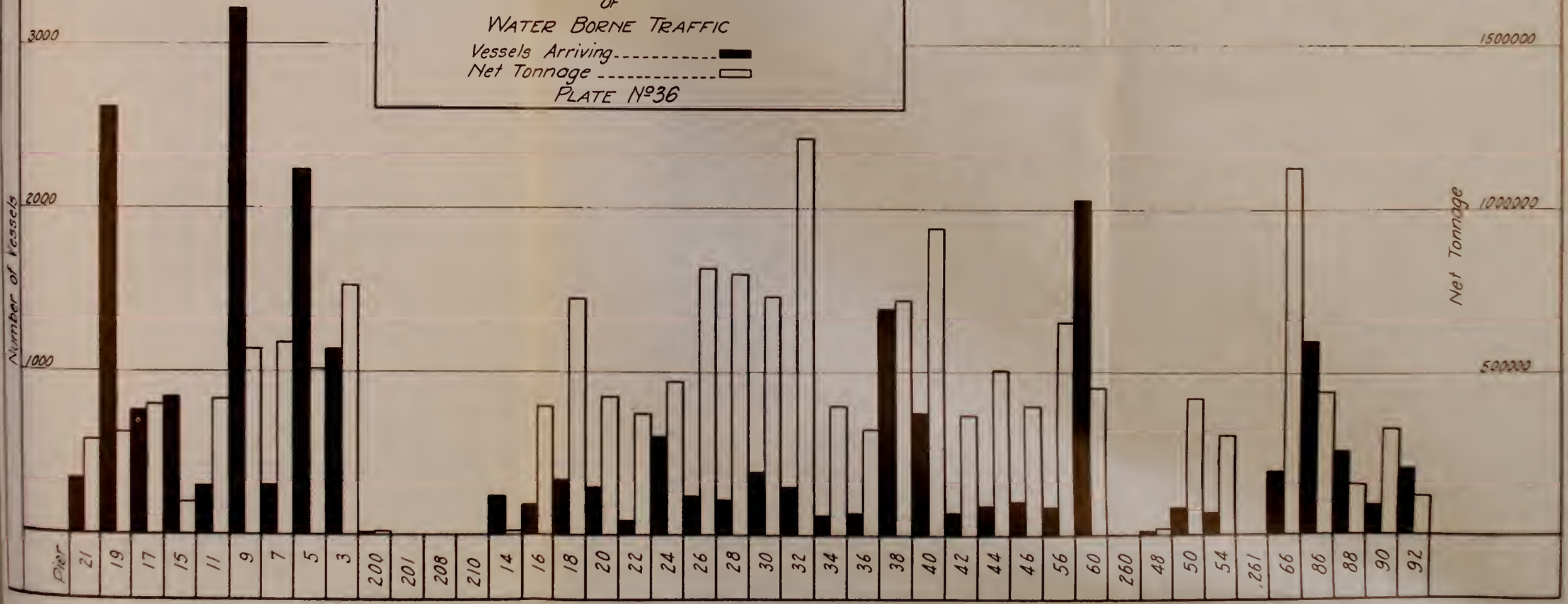
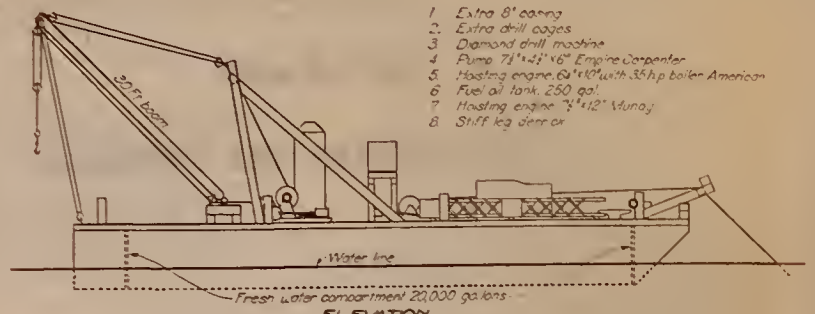


Plate No. 37

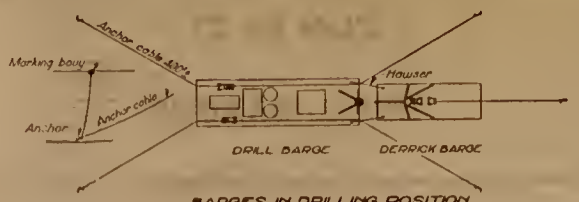
DRILL BARGES


1 Extra 8' casing
2. Extra drill cages
3 Diamond drill machine
4 Pump 7½"x4½"x6" Empire Carpenter
5. Hoisting engine, 6¾"x10" with 35 hp boiler American
6 Fuel oil tank, 250 gal
7 Hoisting engine 7½"x12" Muney
8 Stiff leg derrick
30 Ft. boom
Water line
Fresh water compartment 20,000 gallons

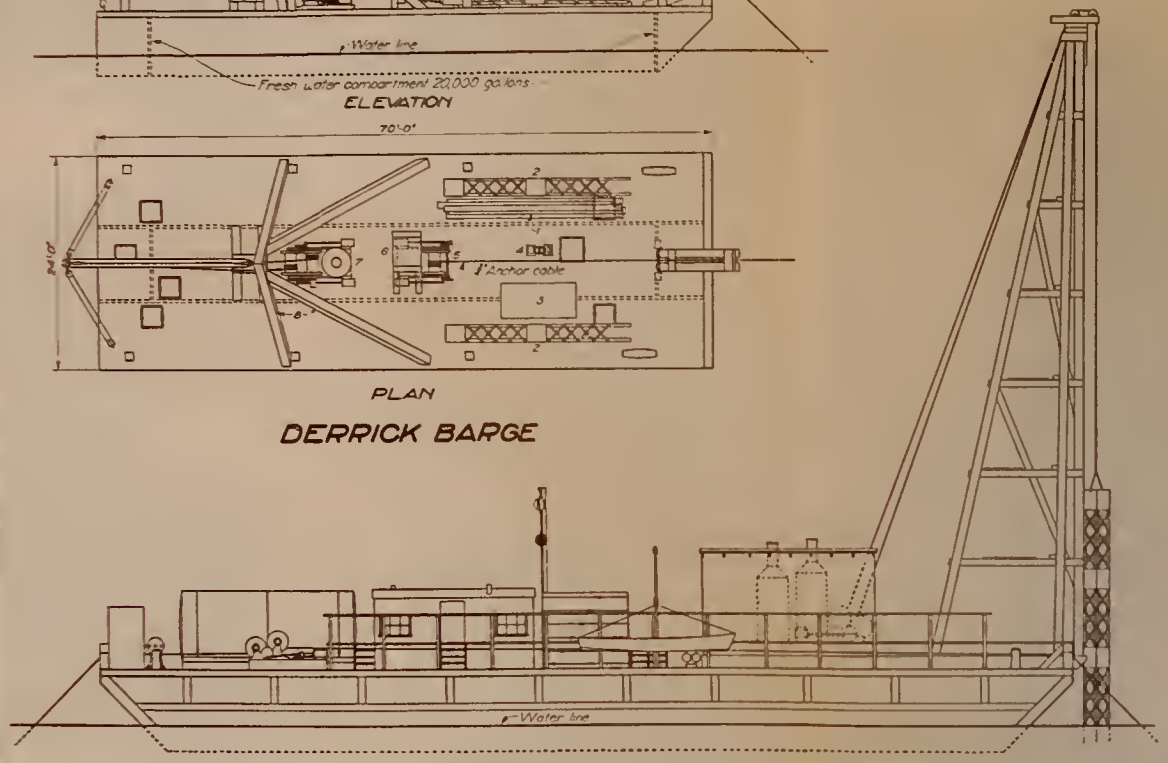
ELEVATION

PLAN

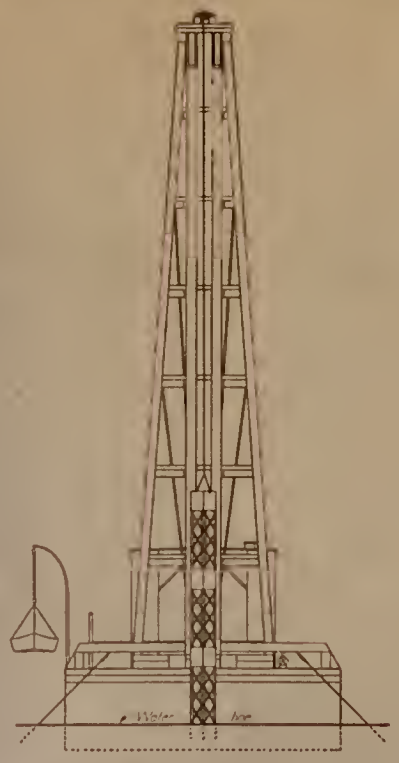
DERRICK BARGE



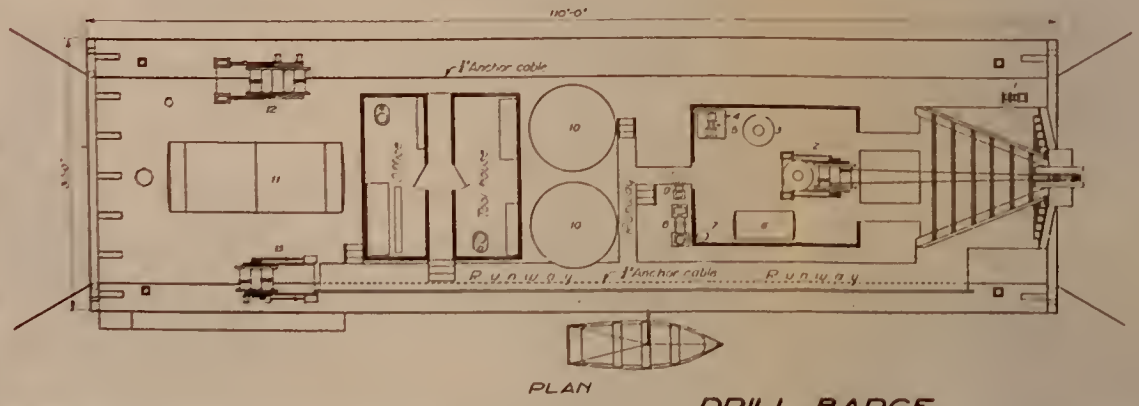
BARGES IN DRILLING POSITION



SIDE ELEVATION



END ELEVATION



PLAN

DRILL BARGE

1 Pump [illegible] diamond drill
4½"x7½"x4" The Sl[illegible] Bacco & Smith Vela Co
2 Hoisting engine
6¾"x10" with 35 hp boiler Lindgerwood
3 Auxiliary boiler for pumps 25 hp American
4 Fuel oil tank 2371 gal
5 Oil pump 4½"x5"x4" Canton Pump Co
6 Fuel oil tank 4[illegible] gal
7 Compressor 9½"x11" single phase [illegible]
8 Pump 10"x5"x10" Geo Dow
9 [illegible] 7½"x4½"x6" Empire Carpenter
10 Water [illegible] 2"x2" [illegible]
11 Fuel oil tank 1000 gal
12 [illegible] engine (anchor) 7½"x10" Lambert, Wis
13 Hoisting engine (anchor) 6¾"x12" Murray, Mass

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION

DRILL BARGES

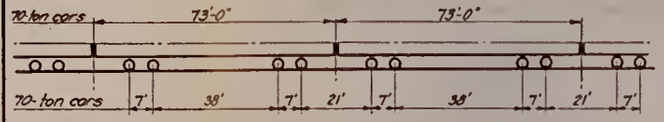
PLATE N°37

Plate No. 38

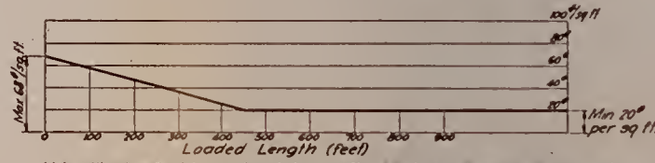
LOADING AND STRESS SHEET

Two continuous lines of 70-ton Electric R.R. cars on outside tracks in opposite directions, or

Four lines of 12-70 ton Electric R.R. cars passing. 80% of stress to be used with this loading

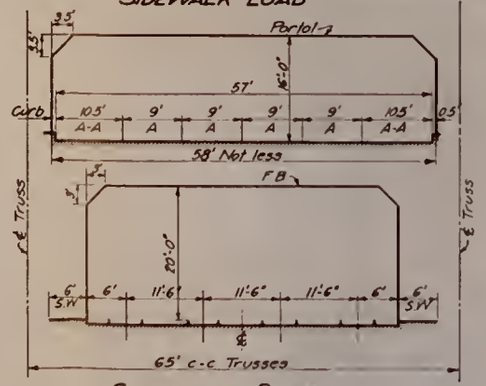


Electric Railway Loading



Note - All sidewalk, stringers, brackets and flooring to be designed to support a live load of not less than 100#/sq. foot of sidewalk area. Loaded width sidewalk 6'-0"

Sidewalk Load



Clearance Diagram

General Notes (Concrete)

All concrete to be Class 'A' six sacks of cement per cubic yard of concrete, except as shown.
For other classes of concrete noted on plans, see specifications of Dept. of Public Works.
All exposed edges to be chamfered one inch.
Reinforcing steel to be square deformed bars tightly wired together at all intersections with No 14 wire.
Where bars are spliced, lap shall be not less than 40 diameters.
All dimensions to steel given to centerline of bar.
All bars to be embedded at least two diameters.

General Notes (Steel)

Specifications - Unless otherwise shown, the structure shall be designed and detailed in accordance with the Standard Specifications for Highway Bridges of the A.A.S.H.O. dated August 1, 1928. All other work shall conform to Standard Specifications of Department of Public Works, Division of Highways, dated January 1930.

Rivets - Diameter 1 1/16" open holes 1 3/16" for main members of spans 720' or greater. For secondary members, small framing of above, and all spans under 720' 7/8" rivets with 15/16" open holes. See detail sheets.

Camber - The exact lengths of all members in the cantilever and anchor arms, including anchorage members; together with all members in the suspended and simple spans shall be computed from deflection diagrams for dead load only.

Loads - The structure shall be proportioned for the following loads:
(a) Dead Load
(b) Live Load
(c) Impact
(d) Wind
(e) Braking
(f) Centrifugal Force

Live Load - For highway live load the 20 ton truck train as shown in diagram was used for slab, stringer, and floor beam design. For structure design the H20 equivalent loading was used for the two outside traffic lanes while the four inside traffic lanes were designed for the H15 equivalent load. Highway L.L. intensity, modified by coefficient C = (18 + W)/n, where W = width of roadway, n = number of traffic lanes.
For design of trusses for electric car live load either two continuous lines of electric cars going in opposite direction on outside tracks, or four passing twelve car electric trains going in the same direction. For this latter loading use only 80% of maximum stress. Floor beams and stringers designed for four passing electric trains going in the same direction. 80% of stress used.
Sidewalk live load shall conform to the following.
Brackets and stringers shall be designed to support a live load of not less than 100#/sq. ft. on a sidewalk width of 6 ft. Girder and trusses to be determined by the following.
P = (80 - 0.125L)(1 - 0.025W) (W to be 6 ft.) Min. = 20#/sq. ft.

Impact - Highway - When W is equal to or less than 18 ft.
I = (L + 250)/(10L + 500)
When W is greater than 18 ft.
I = (36/W + 18)(L + 250)/(10L + 500)
Electric Railway - I = (L + 900)/(12L + 1200)
Max. I for highway = 30%
Where L = loaded length in feet.
For application of loading see design specifications.

Wind - The wind force on the structure shall be assumed as a moving load equivalent to 30#/sq. ft. on the side area of any exposed floor construction, the side area of all railings, and 1½ times the side area of one truss.
The lateral force due to the moving highway live load and the wind pressure against it shall be considered as acting 6' above crown of roadway. This load is equal to 150#/lin. ft.
The lateral force due to the moving electric railway live load and the wind pressure against it shall be considered as acting 8' above top of rail on one track and shall be equivalent to 300#/lin. ft.

Braking - Longitudinal force equal to 20% of the moving railroad live load applied to one track only, at top of rail shall be used in design of ties, rails, stringers, floor beams, and trusses.

Centrifugal Force - Structures on curve carrying electric railroad traffic shall be designed to resist a lateral force equal to 10% of the moving railroad load without impact allowance. This load assumed to act 6 ft. above top of rail.

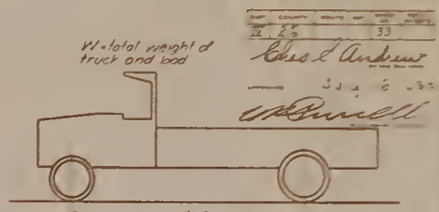
Payment - Payment shall be made on the pound price basis as mentioned in the design specifications.

Physical Requirements:

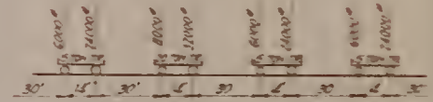
Carbon Steel -	Min. ultimate resistance	65000#/sq. in.
	Min. elastic limit	33000#/sq. in.
	Min. elongation	22% in 8 inches
	Working stress	16000#/sq. in.
Heat treated eye bars -	Min. ultimate resistance	80000#/sq. in.
	Min. elastic limit	52000#/sq. in.
	Min. elongation	6% in 18 ft.
	Working stress	24000#/sq. in.
Silicon Steel -	Min. ultimate resistance	90000#/sq. in.
	Min. elastic limit	45000#/sq. in.
	Min. elongation	18% in 8 inches
	Working stress	24000#/sq. in.
Rivet Steel -	Min. ultimate resistance	55000#/sq. in.
	Min. elastic limit	28000#/sq. in.
	Min. elongation	28% in 8 inches
	Working stress	24000#/sq. in.
Steel Castings -	Min. ultimate resistance	65000#/sq. in.
	Min. elastic limit	35000#/sq. in.
	Min. elongation	20% in 2 inches
	Working stress	12000#/sq. in.

DL and LL unit stresses increased 25% with the addition of wind stresses.

Earthquake Stresses - An allowance of 10% of gravity has been used in the design of foundations and 6% of gravity in the superstructure.

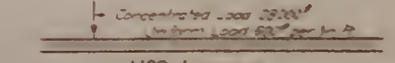

W = total weight of truck and load
16'-0"
Width of each rear tire equals 1 inch per ton of total weight of loaded truck
9'-0"
Clearance & Care Not
1'-6"
6'-0"
1'-6"

Truck (15 or 20 Ton)

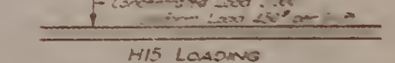


H20 Loading

H15 Loading



H20 Loading



H15 Loading

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION

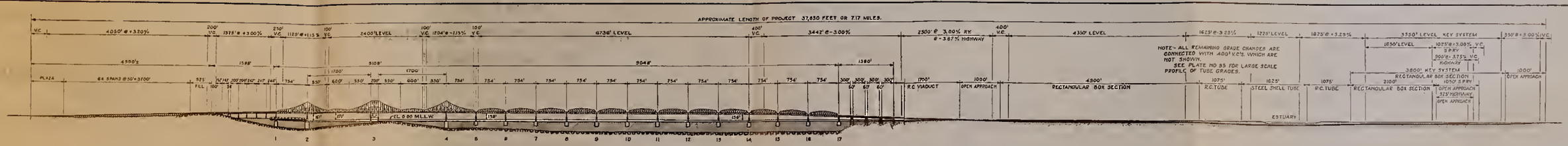
DESIGN SPECIFICATIONS AND GENERAL NOTES

PLATE NO 30

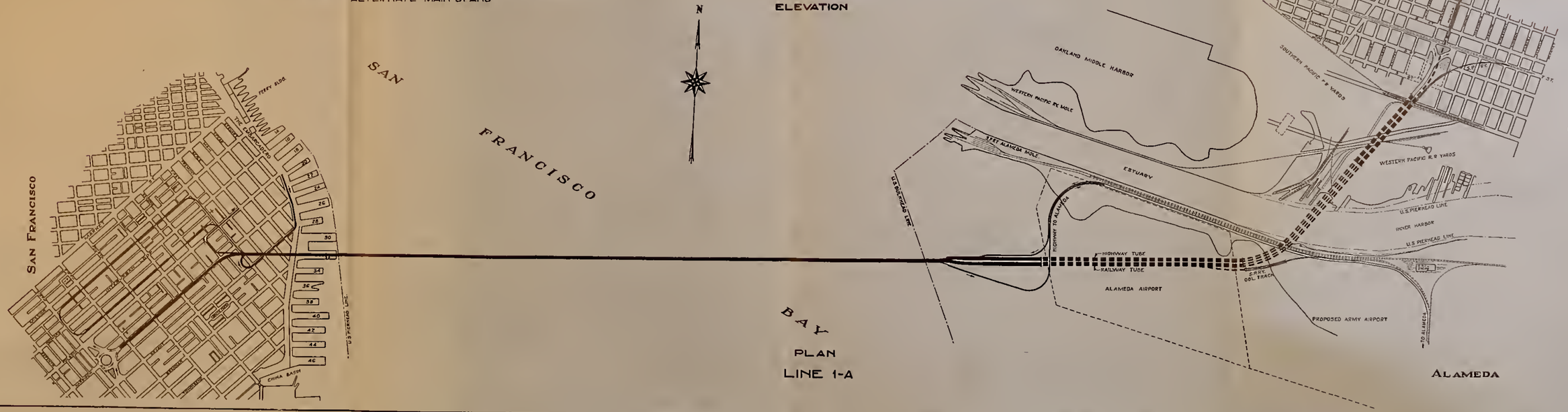
PLAN NO.

Plate No. 39

GENERAL LAYOUT, LOCATIONS Nos. 1-A, 1-B AND 1-C



ALTERNATE MAIN SPANS



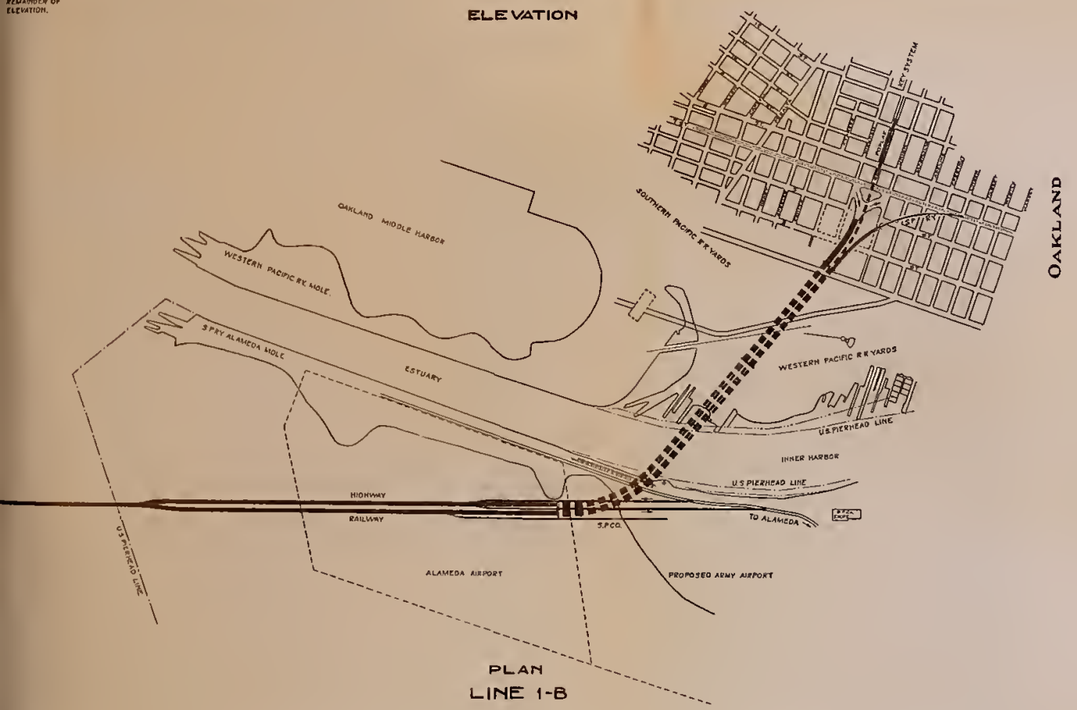
APPROXIMATE LENGTH OF PROJECT 37,850 FEET OR 7.17 MILES

5538'@-3.00% HIGHWAY
4735'@-3.00% R.Y.
460'V.C.
3234' LEVEL HWY
4084' LEVEL R.Y.
400'V.C.
2150'@-3.25
2100'@-3.29½ R.Y.
480'V.C.
REMAINING GRADES SAME AS LINE 1-A

3048'
1380'
754'
300' 300' 300' 300'
60' 60' 60'
1100' R.C. VIADUCT
4700' FILL
800' OPEN APPROACH
400' RECT. BOX
DIMENSIONS SAME AS LINE 1-A.
ESTUARY

NOTE:- SEE LINE 1-A FOR REMAINDER OF ELEVATION.

ELEVATION



PLAN
LINE 1-B

APPROXIMATE LENGTH OF PROJECT 36,860 FEET OR 6.98 MILES.

10,305' LEVEL
400' V.C.
2465'@-3.00%
1200' V.C.
2885'@+3.00%
400' V.C.
1000' LEVEL
400' V.C.
5080'@-2.80% S.P.R.Y. & KEY SYSTEM.
7000'@-2.60% HIGHWAY.

10,555'
9900'
1800'
1000'
4220'
42 SPANS @ 80'-1200' HIGHWAY
14 SPANS @ 80'-1300' S.P.R.Y. & KEY SYSTEM
754' 754' 754' 754' 754' 754'
300' 300' 300'

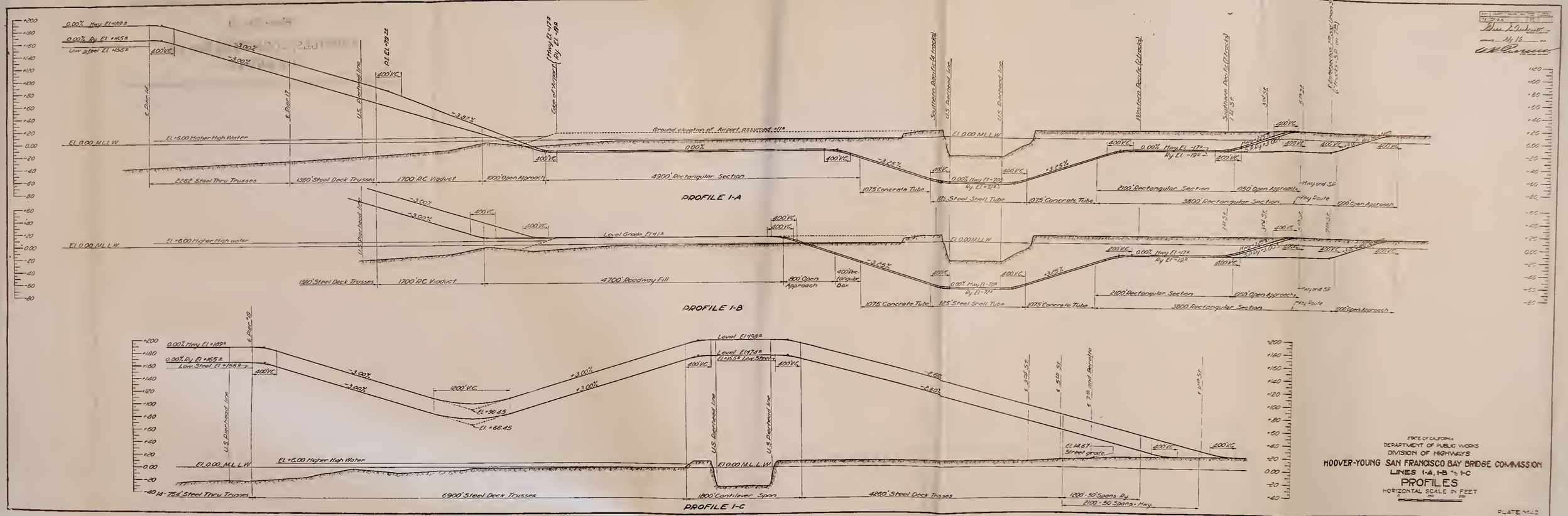

0.00% Hwy. El. +189.2
0.00% Ry. El. +165.2
Low steel El. +156.2
400' V.C.
-3.00%
-3.00%
-3.82%
E. Pier 16
E. Pier 17
U.S. Pierhead line
P.I. El. +79.44
Edge of airport (Hwy El. +172 Ry El. +152)
Ground situation of Airport assumed +11.2
Southern Pacific (4 tracks)
U.S. Pierhead line
U.S. Pierhead line
Western Pacific (4 tracks)
Southern Pacific (2 tracks)
3rd St.
3rd St.
5th St.
(4 tracks on 2nd deck)
El. 0.00 M.L.L.W.
El. +5.00 Higher High Water
0.00%
+3.65%
0.00% Hwy El. +179.2
Ry El. +159.2
400' V.C.
0.00% Hwy El. +70.2
Ry El. +70.2
2262' Steel Thru Trusses
1380' Steel Deck Trusses
1700' R.C. Viaduct
1000' Open Approach
4900' Rectangular Section
1075' Concrete Tube
1125' Steel Shell Tube
1075' Concrete Tube
2100' Rectangular Section
1150' Open Approach
Hwy and SP
3800' Rectangular Section
Hwy Route
1000' Open Approach
PROFILE 1-A
U.S. Pierhead line
Level Grade El. 141.2
-3.00%
-3.00%
400' V.C.
200' V.C.
El. 0.00 M.L.L.W.
El. +5.00 Higher High water
0.00% Hwy El. +179.2
Ry El. +159.2
0.00% Hwy El. +70.2
Ry El. +70.2
+3.65%
-3.65%
1380' Steel Deck Trusses
1700' R.C. Viaduct
4700' Roadway Fill
800' Open Approach
400' Rectangular Box
1075' Concrete Tube
1125' Steel Shell Tube
1075' Concrete Tube
2100' Rectangular Section
1150' Open Approach
Hwy and SP
3800' Rectangular Section
Hwy Route
1000' Open Approach
PROFILE 1-B
E. Pier 30
0.00% Hwy El. +189.2
0.00% Ry El. +165.2
Low Steel El. +156.2
400' V.C.
-3.00%
-3.00%
1200' V.C.
+3.00%
+3.00%
El. +30.45
El. +66.45
Level El. 138.2
Level El. 174.2
El. 165.2 Low Steel
400' V.C.
-2.60%
-2.60%
E. 3rd St.
E. 4th St.
E. 7th and Arcade
E. 14th St.
U.S. Pierhead line
U.S. Pierhead line
U.S. Pierhead line
El. 0.00 M.L.L.W.
El. +5.00 Higher High Water
El. 14.67 Street grade
400' V.C.
400' V.C.
754' Steel Thru Trusses
6900' Steel Deck Trusses
1800' Cantilever Span
4260' Steel Deck Trusses
1200-50' Spans Ry.
2100-50' Spans - Hwy.
PROFILE 1-C
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
LINES 1-A, 1-B & 1-C
PROFILES
HORIZONTAL SCALE IN FEET
PLATE No. 10

Plate No. 41

PROFILES, LOCATIONS Nos. 3 AND 4

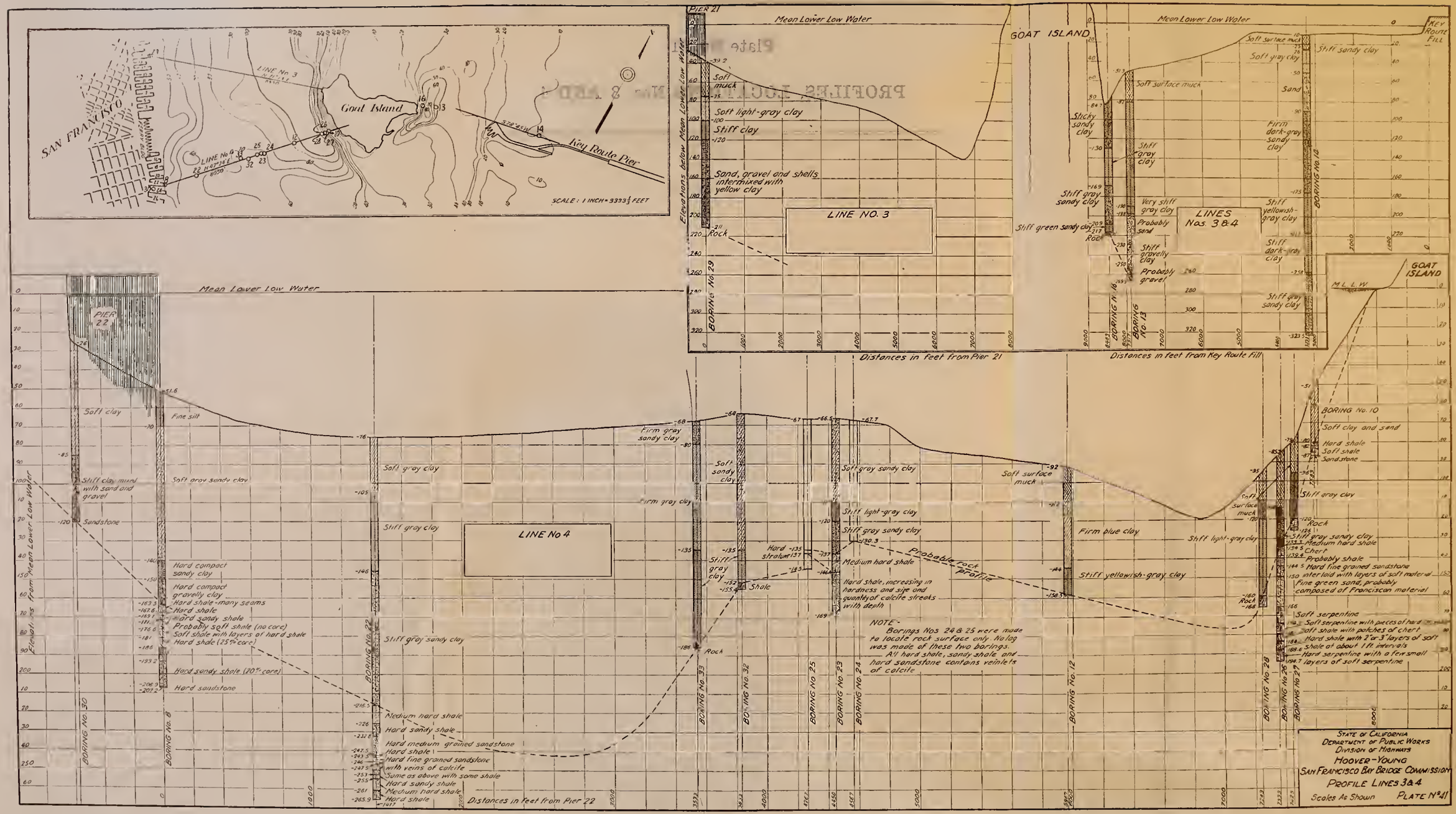

SAN FRANCISCO
Goat Island
Key Route Pier
LINE No 3
LINE No 4
SCALE: 1 INCH = 9333⅓ FEET
PIER 21
Mean Lower Low Water
Elevations below Mean Lower Low Water
Soft muck
Soft light-gray clay
Stiff clay
Sand, gravel and shells intermixed with yellow clay
Rock
LINE NO. 3
BORING No 29
Distances in feet from Pier 21
GOAT ISLAND
Key Route Fill
Soft surface muck
Soft gray clay
Stiff sandy clay
Sand
Sticky sandy clay
Firm dark-gray sandy clay
Stiff gray clay
Stiff gray sandy clay
Very stiff gray clay
Stiff yellowish-gray clay
Probably sand
Stiff green sandy clay
Stiff gravelly clay
Probably gravel
Stiff dark-gray clay
Stiff gray sandy clay
LINES Nos. 3 & 4
BORING No. 13
BORING No. 12
Distances in feet from Key Route Fill
PIER 22
Soft clay
Fine silt
Stiff clay mixed with sand and gravel
Soft grey sandy clay
Sandstone
Soft gray clay
Stiff gray clay
Hard compact sandy clay
Hard compact gravelly clay
Hard shale - many seams
Hard shale
Hard sandy shale
Probably soft shale (no core)
Soft shale with layers of hard shale
Hard shale (25% core)
Hard sandy shale (70% core)
Hard sandstone
Stiff gray sandy clay
Medium hard shale
Hard sandy shale
Hard medium grained sandstone
Hard shale
Hard fine grained sandstone with veins of calcite
Same as above with some shale
Hard sandy shale
Medium hard shale
Hard shale
LINE No 4
Firm gray sandy clay
Soft sandy clay
Firm gray clay
Stiff gray clay
Shale
Rock
Soft gray sandy clay
Soft surface muck
Stiff light-gray clay
Stiff gray sandy clay
Hard stratum
Medium hard shale
Probable rock profile
Hard shale, increasing in hardness and size and quantity of calcite streaks with depth
Firm blue clay
Stiff yellowish-gray clay
NOTE - Borings Nos 24 & 25 were made to locate rock surface only. No log was made of these two borings. All hard shale, sandy shale and hard sandstone contains veinlets of calcite
BORING No 30
BORING No 8
BORING No 22
BORING No 33
BORING No 32
BORING No 25
BORING No 23
BORING No 24
BORING No. 12
BORING No 28
BORING No 26
BORING No 27
Distances in feet from Pier 22
GOAT ISLAND
M L L W
BORING No. 10
Soft clay and sand
Hard shale
Soft shale
Sandstone
Stiff gray clay
Rock
Stiff gray sandy clay
Medium hard shale
Chert
Probably shale
Hard fine grained sandstone interlaid with layers of soft material
Fine green sand, probably composed of Franciscan material
Soft serpentine
Soft serpentine with pieces of hard
Soft shale with patches of chert
Hard shale with 2' or 3' layers of soft shale at about 1 ft. intervals
Hard serpentine with a few small layers of soft serpentine
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
PROFILE LINES 3 & 4
Scales As Shown
PLATE No 41

Plate No. 42

GENERAL PLAN, LOCATION No. 3

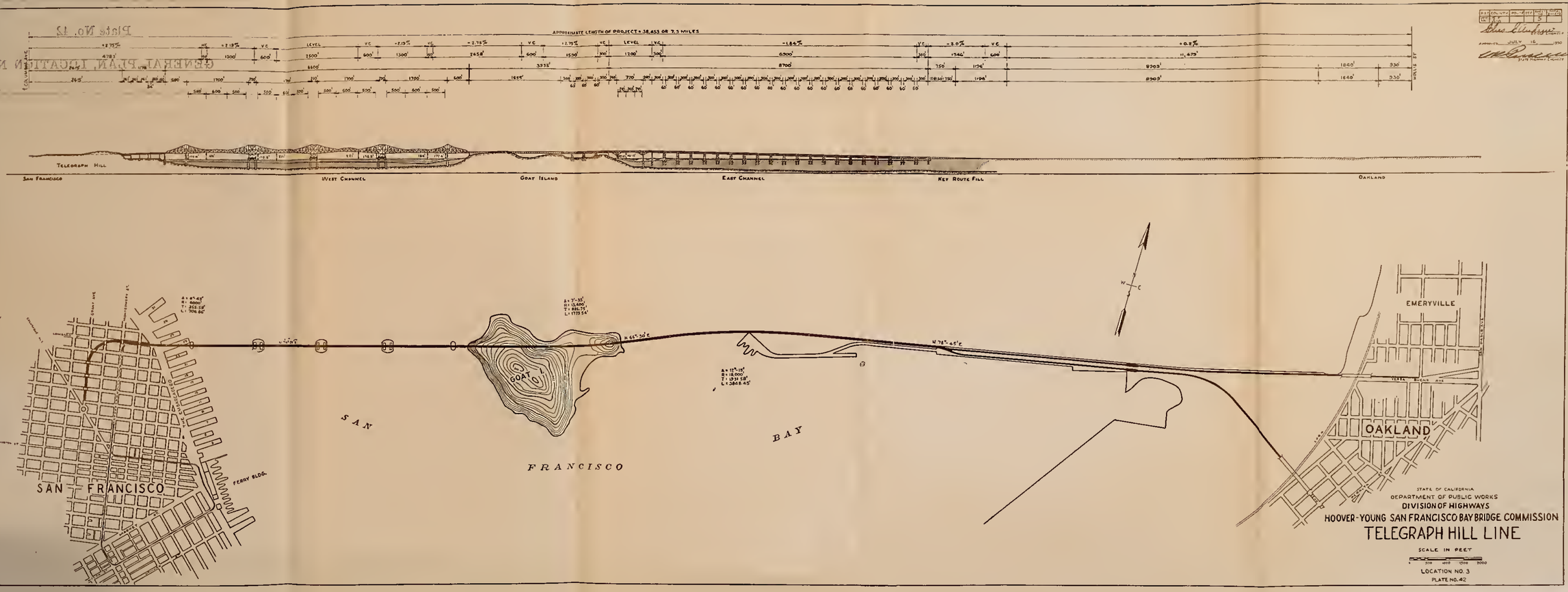
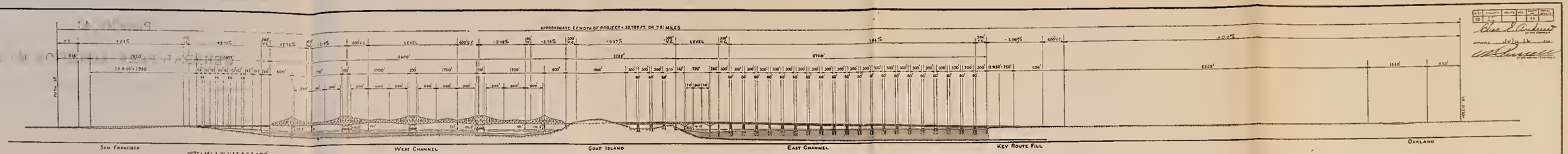
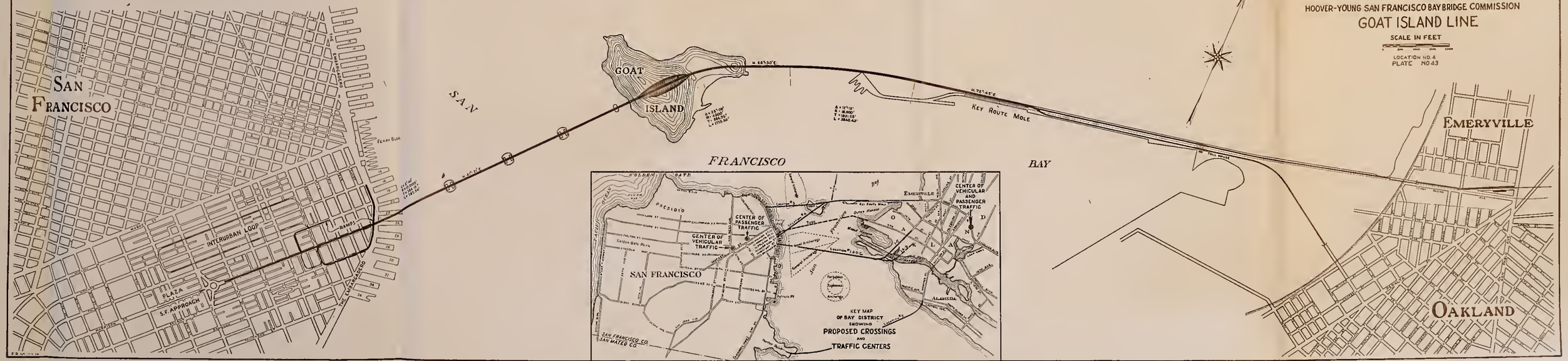

APPROXIMATE LENGTH OF PROJECT = 38,453 OR 7.3 MILES
TELEGRAPH HILL
SAN FRANCISCO
WEST CHANNEL
GOAT ISLAND
EAST CHANNEL
KEY ROUTE FILL
OAKLAND
SAN FRANCISCO
FERRY BLDG.
GOAT I.
SAN FRANCISCO BAY
EMERYVILLE
OAKLAND
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
TELEGRAPH HILL LINE
SCALE IN FEET
LOCATION NO. 3
PLATE No. 42

Plate No. 43

GENERAL PLAN, LOCATION No. 4





STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION

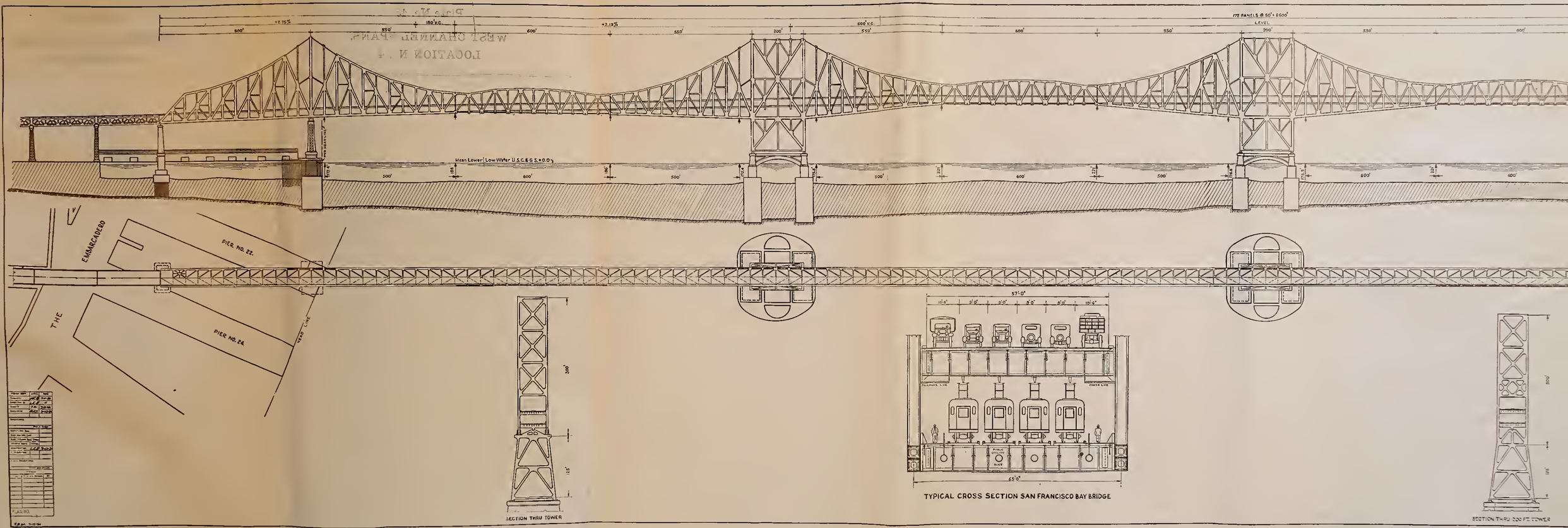
GOAT ISLAND LINE

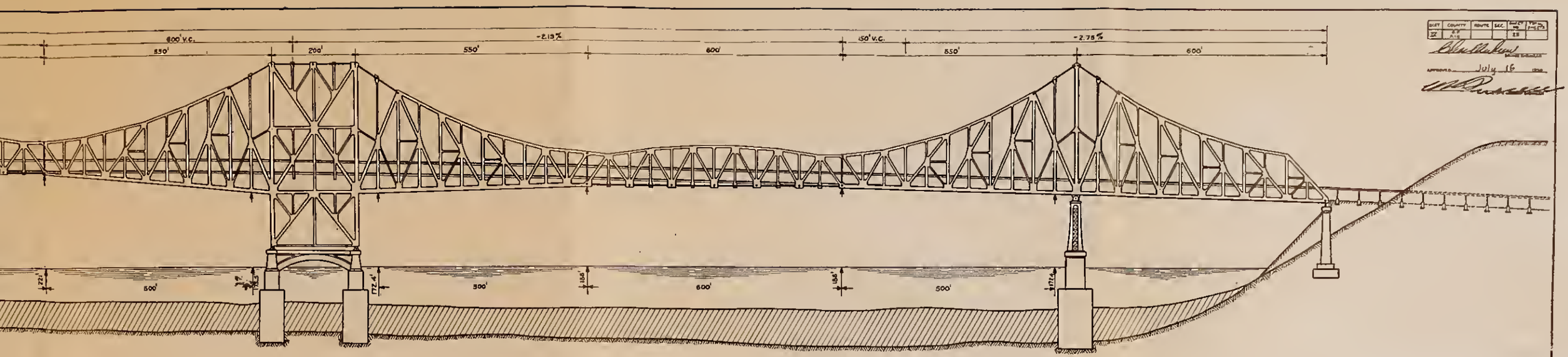
SCALE IN FEET

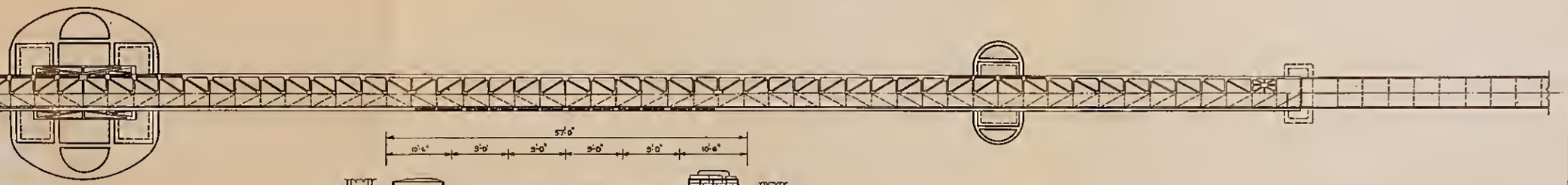
LOCATION NO. 4
PLATE NO. 43

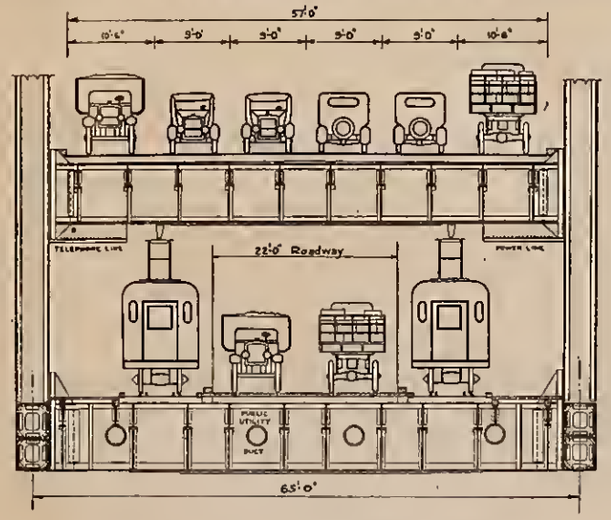
Plate No. 45

WEST CHANNEL SPANS, LOCATION No. 4


EMBARCADERO
PIER NO. 22.
PIER NO. 24.
THE
SECTION THRU TOWER
57'-0"
65'-0"
TYPICAL CROSS SECTION SAN FRANCISCO BAY BRIDGE
SECTION THRU 220 FT. TOWER







ALTERNATE SECTION SAN FRANCISCO BAY BRIDGE

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
GOAT ISLAND LINE

WEST CHANNEL SPANS

SCALE IN FEET

LOCATION NO. 4.

PLATE NO. 45.

Plate No. 46

GOAT ISLAND CROSSING, LOCATION No. 4

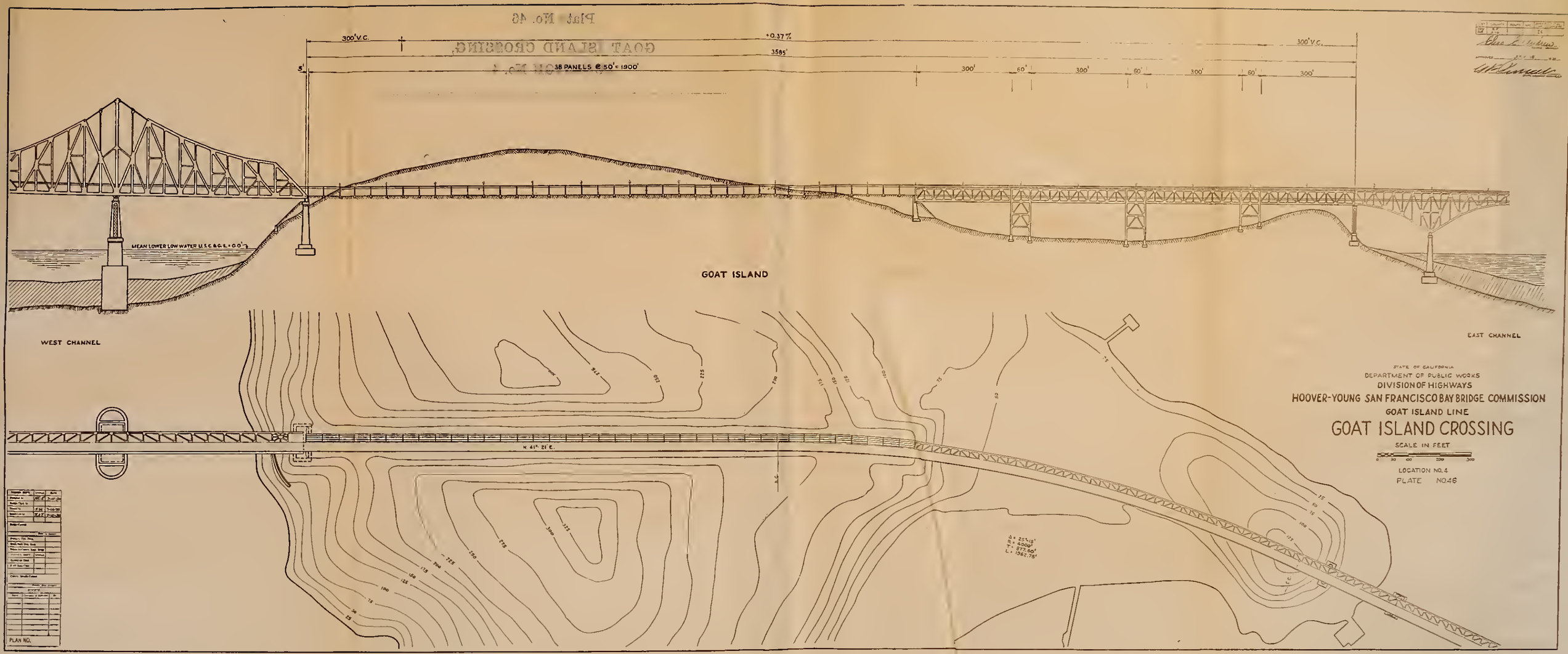
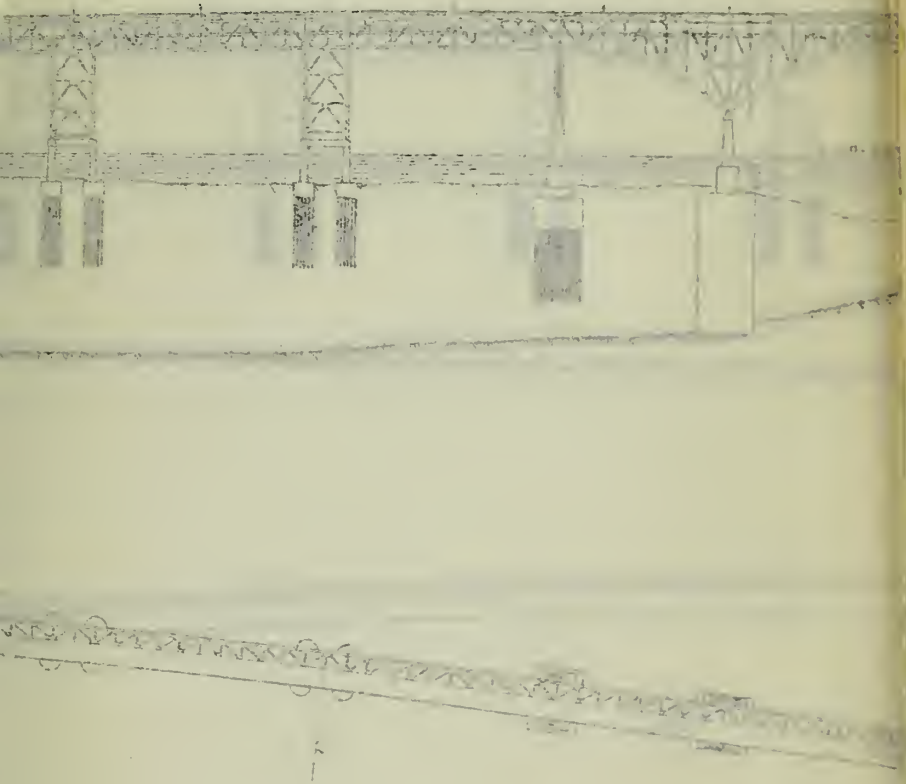
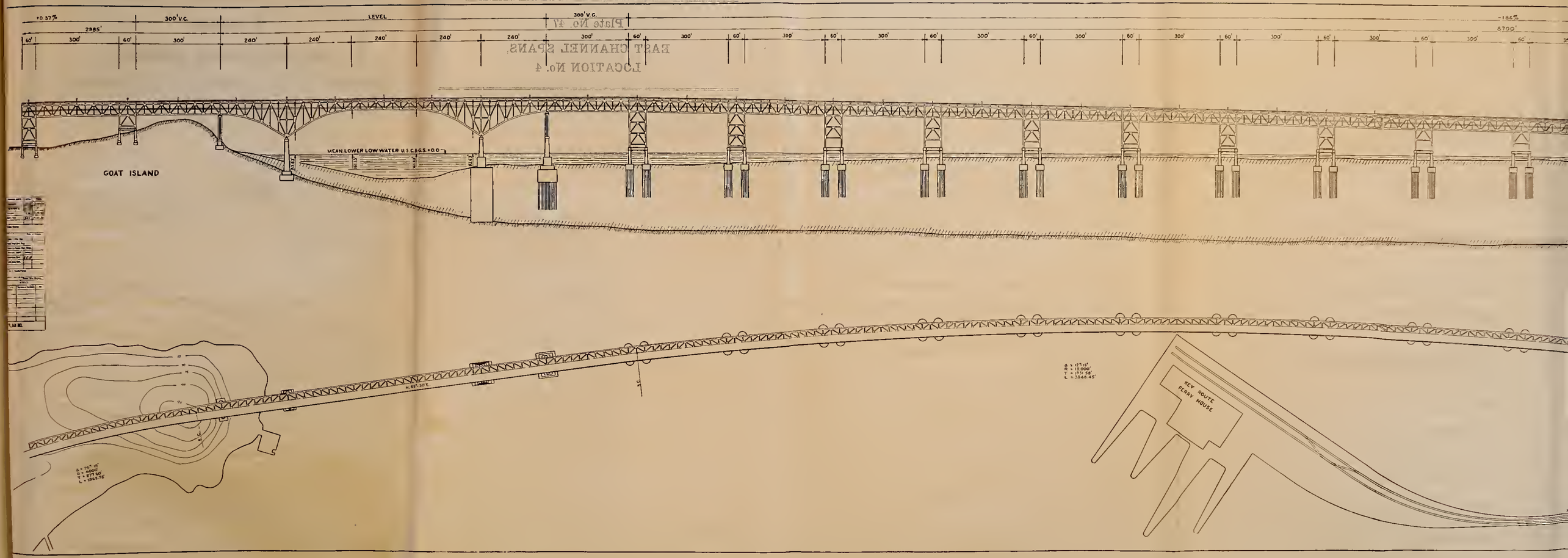
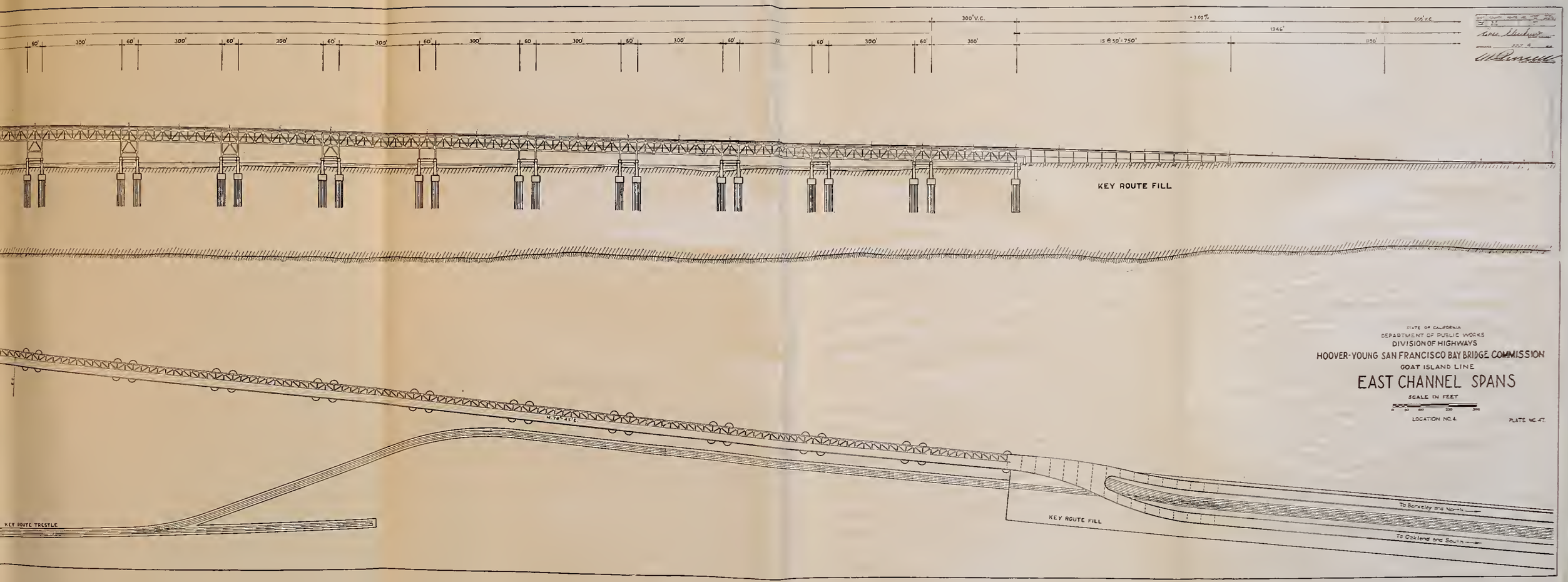

300'V.C.
+0.37%
3585'
38 PANELS @ 50' = 1900'
300'V.C.
300'
60'
300'
60'
300'
60'
300'
MEAN LOWER LOW WATER U.S.C.&G.S. = 0.0'
GOAT ISLAND
WEST CHANNEL
EAST CHANNEL
N 41° 21' E.
Δ = 25°15'
R = 4000'
T = 877.60'
L = 1762.78'
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
GOAT ISLAND LINE
GOAT ISLAND CROSSING
SCALE IN FEET
0 30 60 120 300
LOCATION NO. 4
PLATE NO. 46
PLAN NO.

Plate No. 47

EAST CHANNEL SPANS, LOCATION No. 4




+0.37%
300' V.C.
LEVEL
300' V.C.
-1.86%
2985'
8700'
60'
300'
240'
GOAT ISLAND
MEAN LOWER LOW WATER U.S.C.&G.S. +0.0
N. 48°-30' E.
KEY ROUTE FERRY HOUSE



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
GOAT ISLAND LINE

EAST CHANNEL SPANS

SCALE IN FEET

LOCATION NO. 4.

PLATE NO. 47.

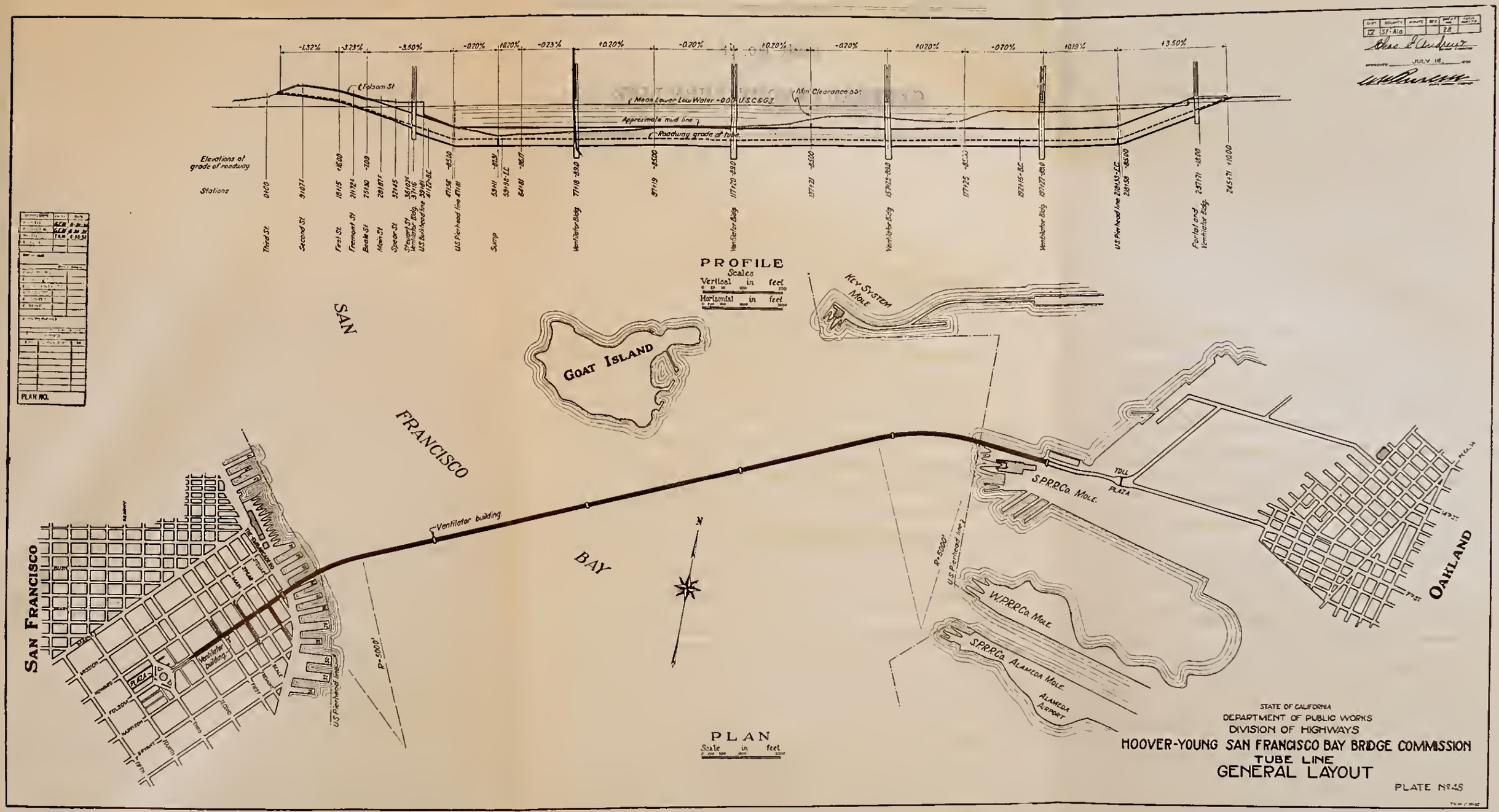
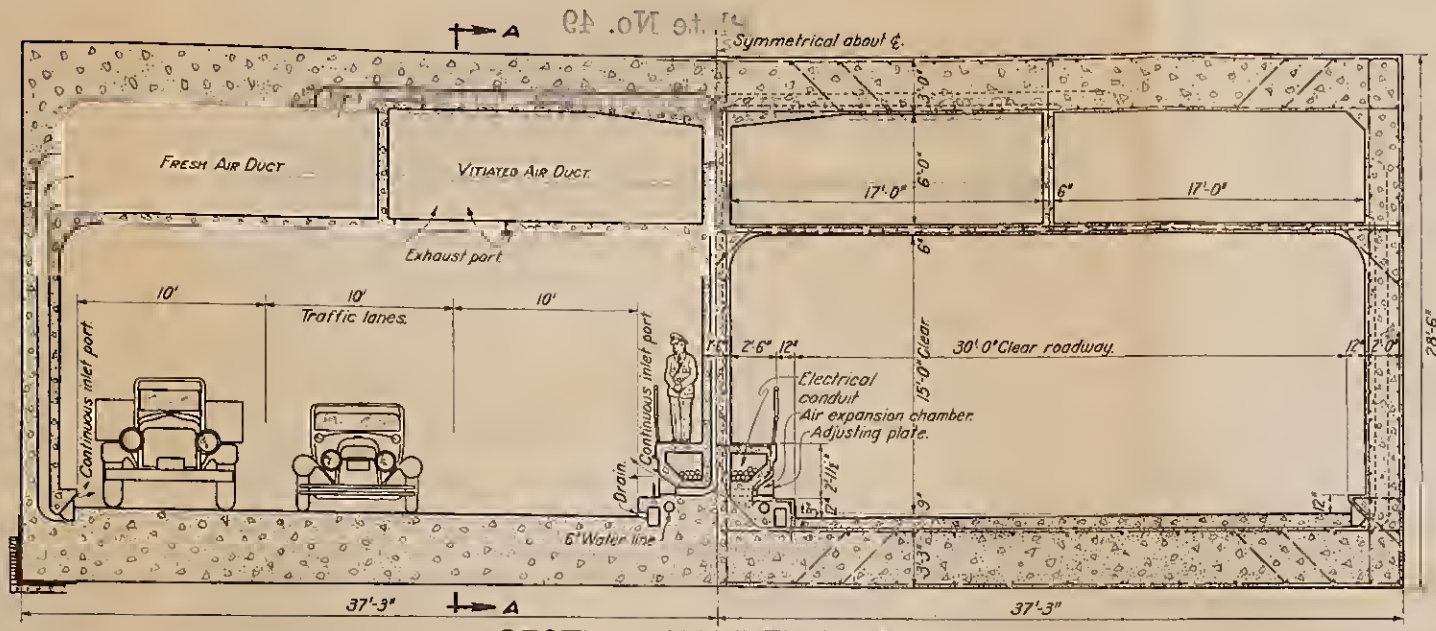
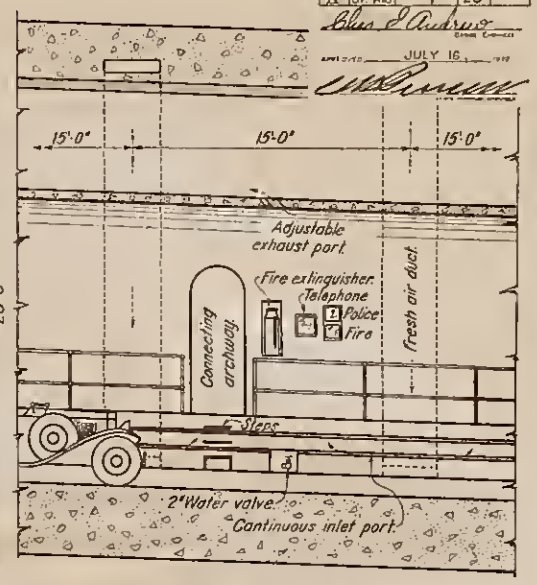

-1.52%
-3.23%
-3.50%
-0.20%
+0.20%
-0.23%
+0.20%
-0.20%
+0.20%
-0.20%
+0.20%
-0.70%
+0.19%
+3.50%
Elevations of grade of roadway
Stations
Third St.
Second St.
First St.
Fremont St.
Beale St.
Main St.
Spear St.
Ventilator Bldg.
U.S. Bulkhead line
U.S. Pierhead line
Sump
Ventilator Bldg.
Ventilator Bldg.
Ventilator Bldg.
Ventilator Bldg.
Ventilator Bldg.
U.S. Pierhead line
Portal and Ventilator Bldg.
Min Clearance 55'
Mean Lower Low Water = 0.0 U.S.C.&G.S.
Approximate mud line
Roadway grade of tube
PROFILE
Scales
Vertical in feet
Horizontal in feet
PLAN
Scale in feet
SAN FRANCISCO BAY
GOAT ISLAND
KEY SYSTEM MOLE
S.P.R.R.Co. MOLE
W.P.R.R.Co. MOLE
S.P.R.R.Co. ALAMEDA MOLE
ALAMEDA AIRPORT
TOLL PLAZA
Ventilator building
U.S. Pierhead line
R=5000'
SAN FRANCISCO
OAKLAND
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
TUBE LINE
GENERAL LAYOUT
PLATE No. 45

Plate No. 49

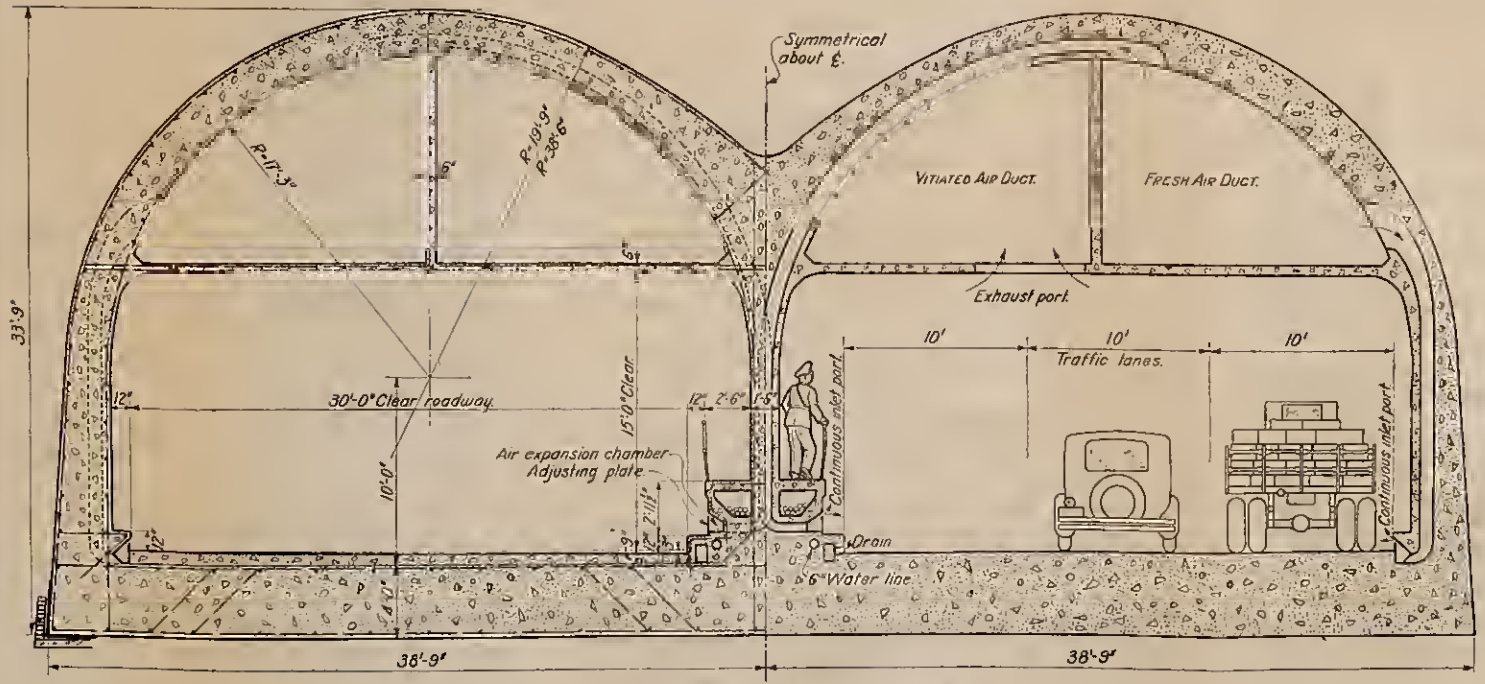
TYPICAL LAND SECTIONS, TUBE LINE



SECTION Nº1 UNDER STREET



SECTION A-A
SIMILAR STATIONS AT EVERY 400 FT.



SECTION Nº2 UNDER STREET

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
TUBE LINE
SAN FRANCISCO APPROACH

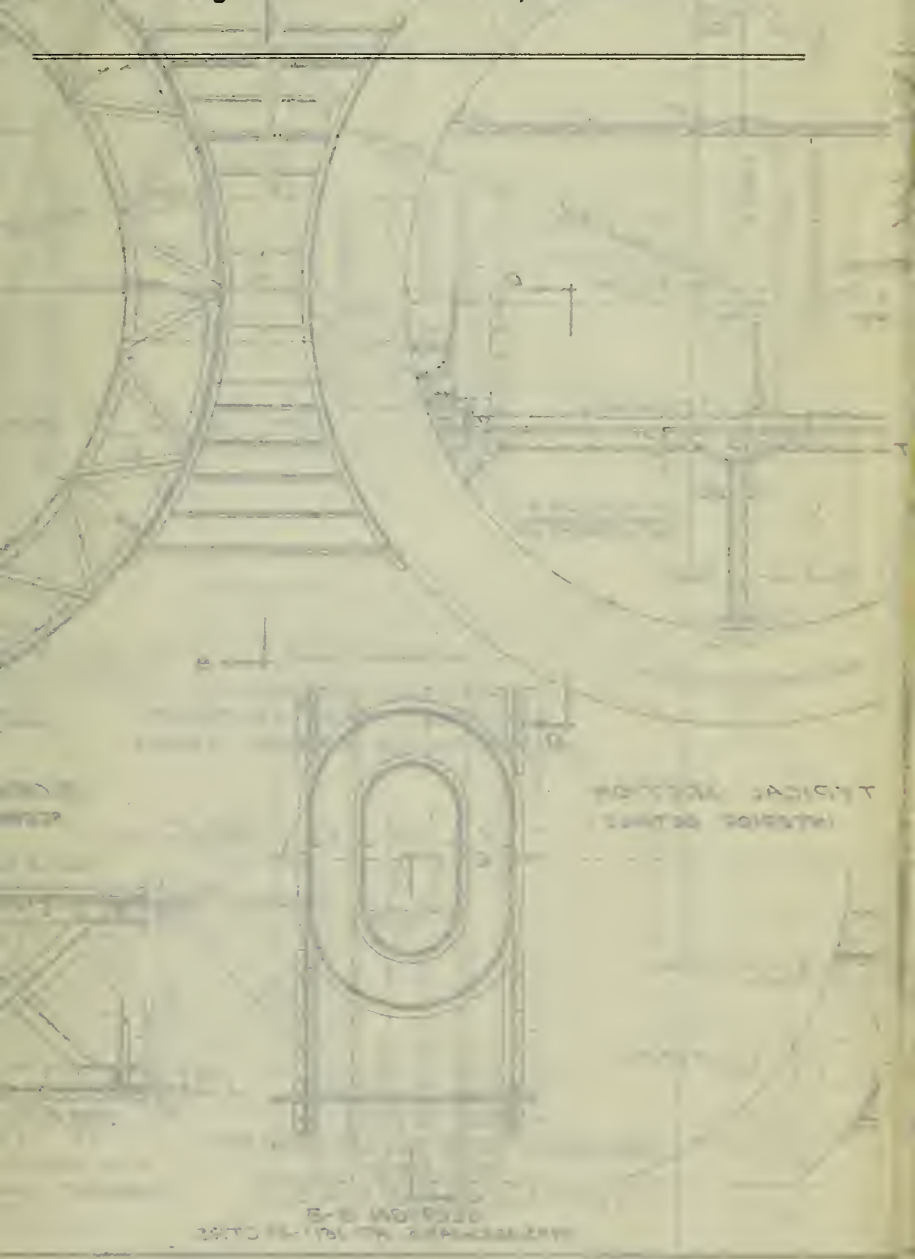
TYPICAL LAND SECTIONS

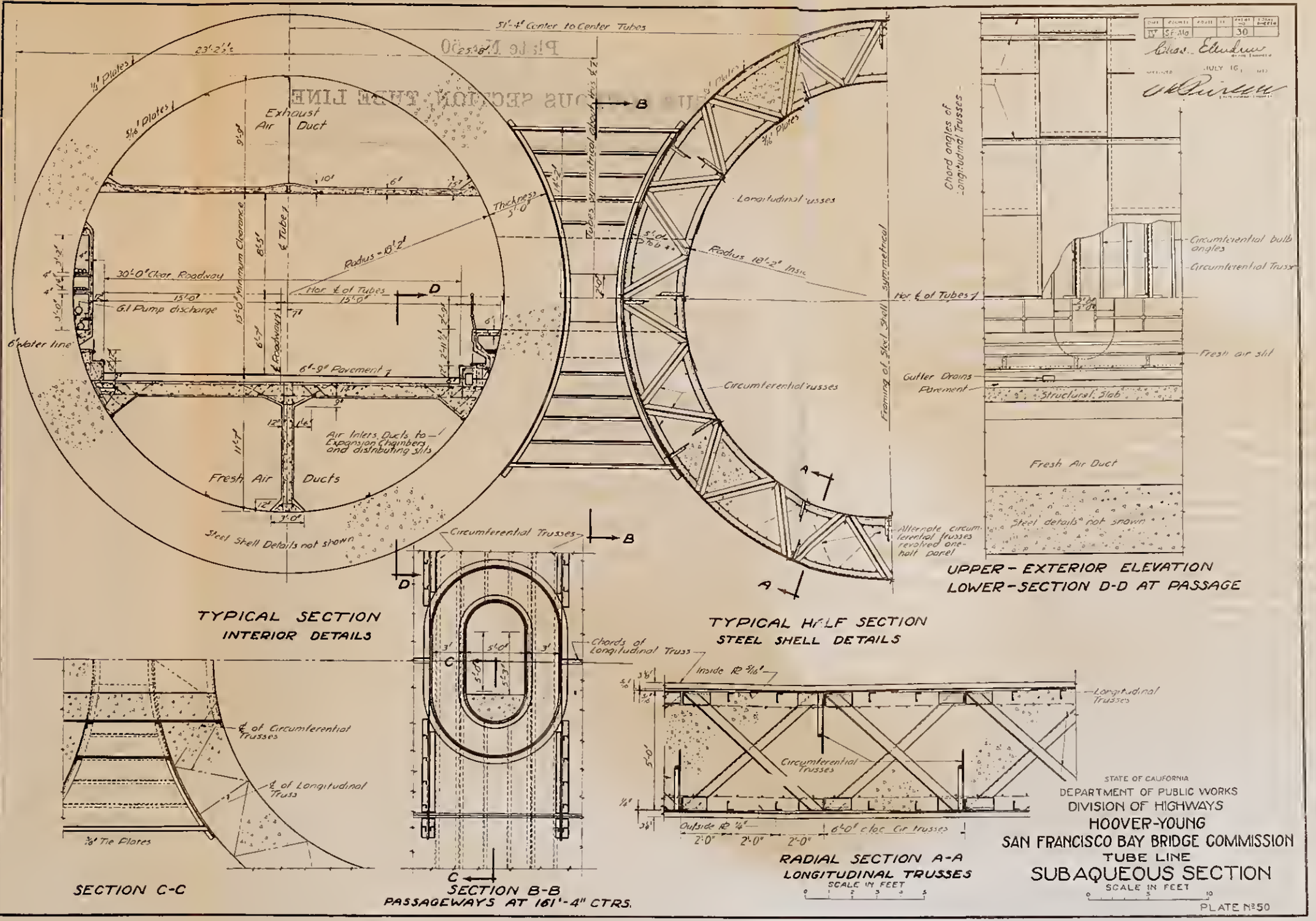
SCALE IN FEET

PLATE Nº 49

Plate No. 50

SUB-AQUEOUS SECTION, TUBE LINE





TYPICAL SECTION
INTERIOR DETAILS

TYPICAL HALF SECTION
STEEL SHELL DETAILS

UPPER - EXTERIOR ELEVATION
LOWER - SECTION D-D AT PASSAGE

SECTION C-C

SECTION B-B
PASSAGEWAYS AT 161'-4" CTRS.

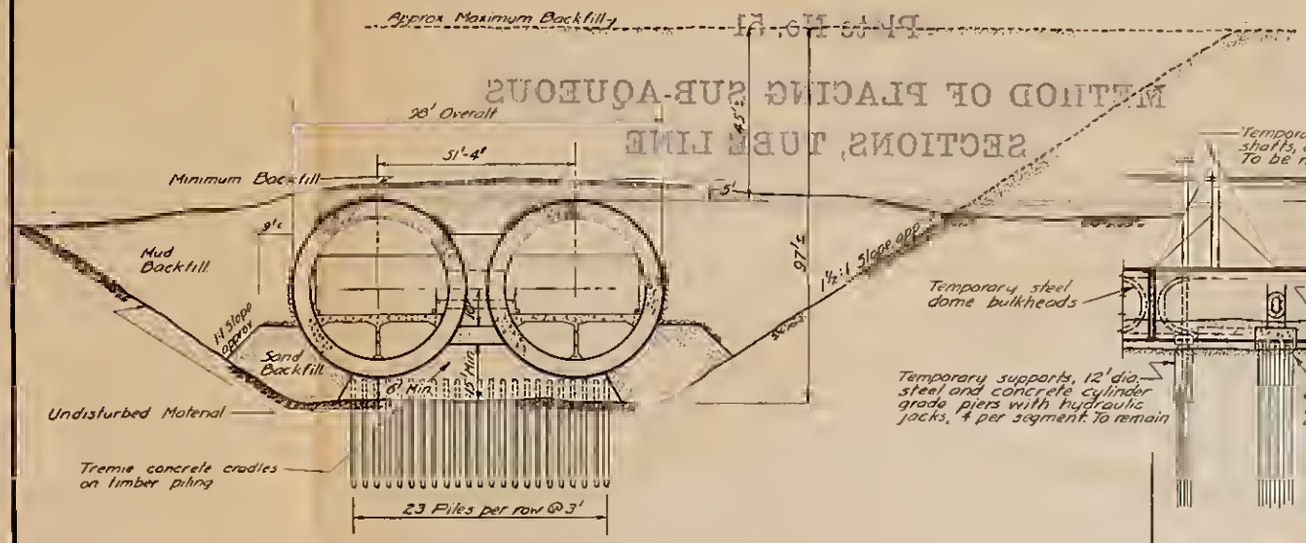
RADIAL SECTION A-A
LONGITUDINAL TRUSSES
SCALE IN FEET
0 1 2 3 4 5

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
TUBE LINE
SUBAQUEOUS SECTION
SCALE IN FEET
0 5 10

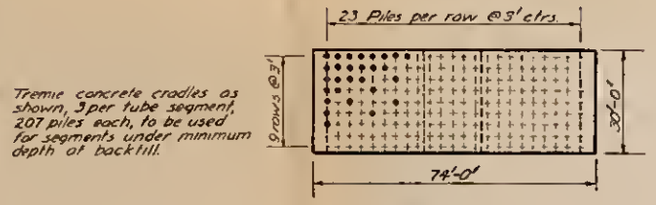
PLATE No 50

Plate No. 51

METHOD OF PLACING SUB-AQUEOUS SECTIONS, TUBE LINE

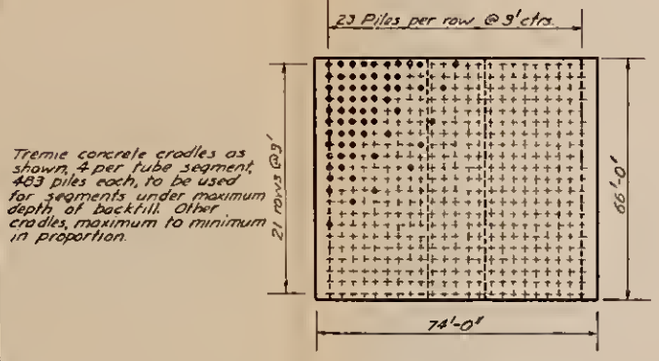


TYPICAL SECTION
TUBES IN FINAL POSITION



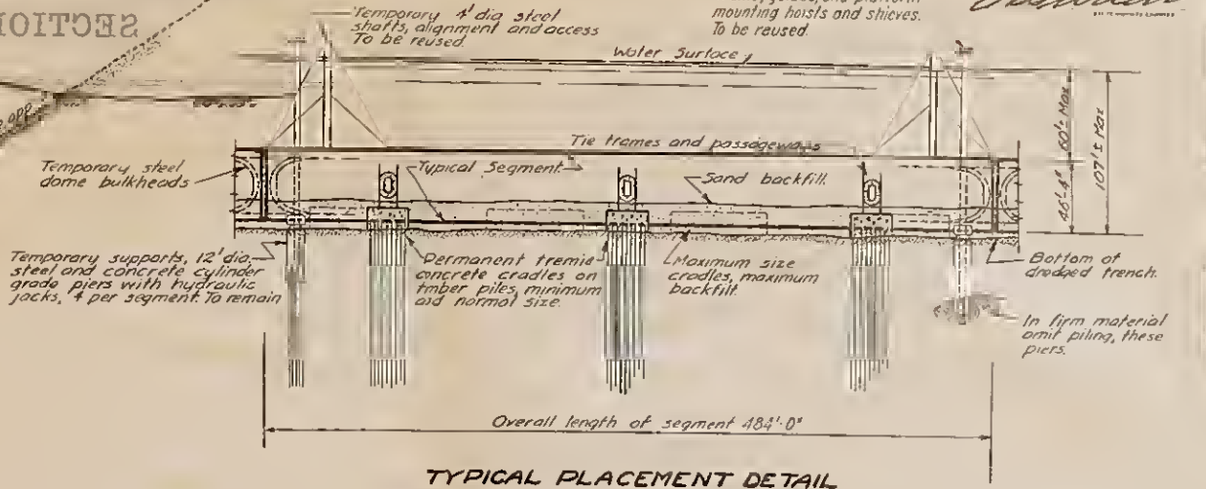
Tremie concrete cradles as shown, 3 per tube segment, 207 piles each, to be used for segments under minimum depth of backfill.

PLAN
MINIMUM CRADLE



Tremie concrete cradles as shown, 4 per tube segment, 483 piles each, to be used for segments under maximum depth of backfill. Other cradles, maximum to minimum in proportion.

PLAN
MAXIMUM CRADLE
SCALE IN FEET
0 1 2 3 4 5 10


Temporary steel gallows frame, guides, and platform mounting hoists and shieves. To be reused.
Temporary 4' dia. steel shafts, alignment and access. To be reused.
Water Surface
Tie tremes and passageways
Temporary steel dome bulkheads
Typical Segment
Sand backfill
60'± Max.
107'± Max.
45'-4"
Temporary supports, 12' dia. steel and concrete cylinder grade piers with hydraulic jacks, 4 per segment. To remain
Permanent tremie concrete cradles on timber piles, minimum and normal size.
Maximum size cradles, maximum backfill
Bottom of dredged trench.
In firm material omit piling, these piers.
Overall length of segment 484'-0"

TYPICAL PLACEMENT DETAIL
SECTION ON CENTERLINE BETWEEN TUBES
SCALE IN FEET
0 1 2 3 4 5 10

IV	SF-Ala			31	

Alice L. Andrew
APPROVED JULY 15, 1930
U. Bonnesen

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
TUBE LINE
SUBAQUEOUS SECTION
METHOD OF PLACING

PLATE Nº 51

Plate No. 52

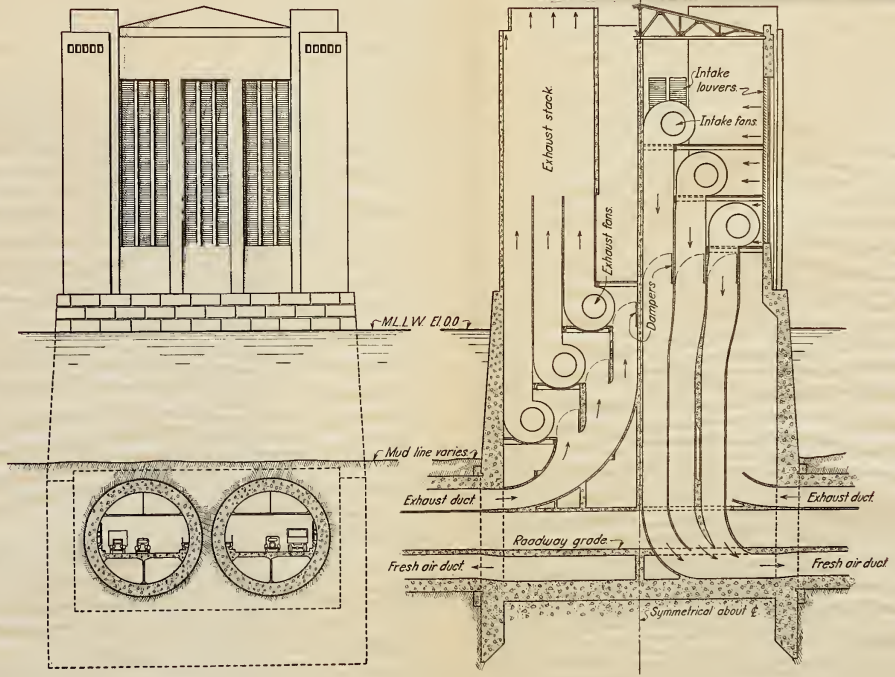
TYPICAL VENTILATION BUILDING, TUBE LINE

DIST	COUNTY	ROUTE	MILE POST NO.	SHEET NO.	TOTAL SHEETS
04	SF-Ala			32	

Chas. E. Andrew
Bridge Engineer

APPROVED JULY 16, 1936

W. H. Burnett
State Highway Engineer



TYPICAL OF 12 EXHAUST FANS

TYPICAL OF 12 INTAKE FANS

HALF SECTIONS

ELEVATION

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
TUBE LINE
VENTILATION BUILDING

SCALE IN FEET 0 10 20 30 40 50

PLATE No 52

FEB 5-16-30

Plate No. 53

GENERAL PLAN, LOCATION No. 5

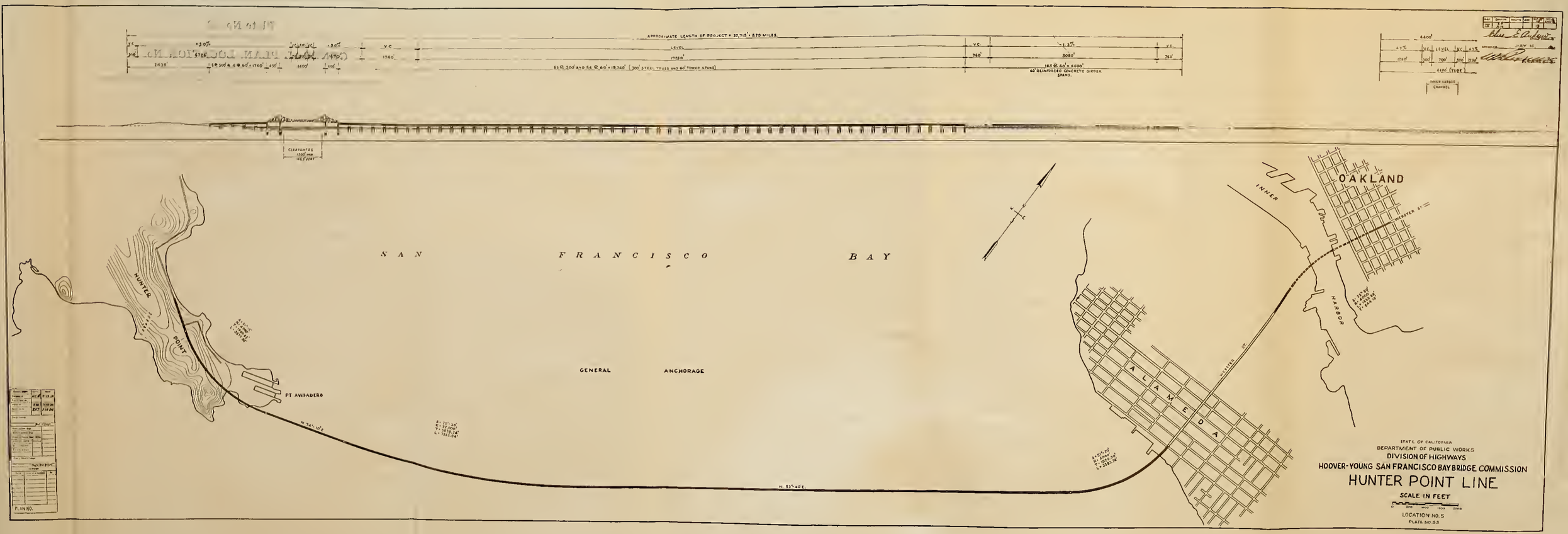
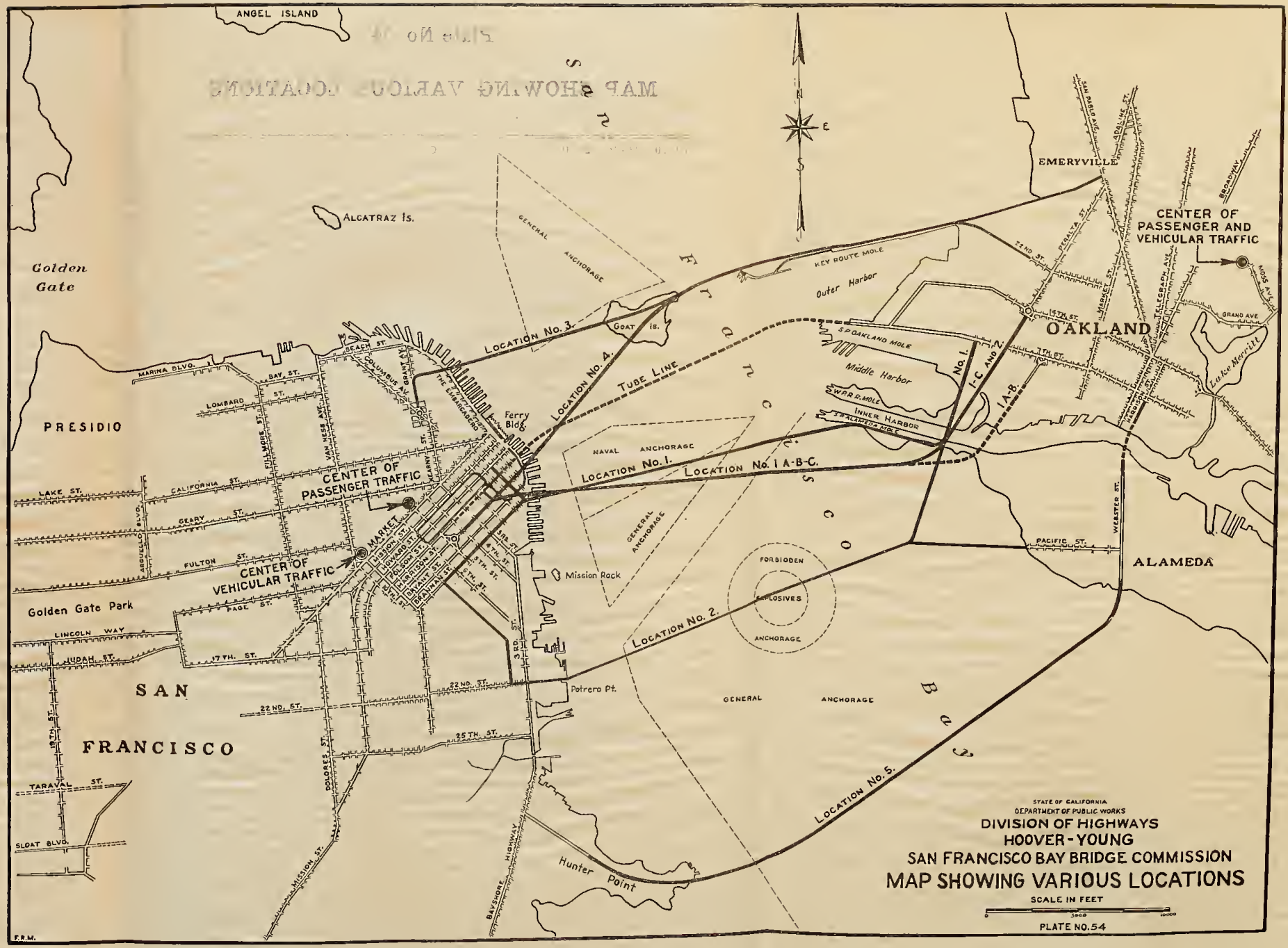

APPROXIMATE LENGTH OF PROJECT = 37,715' = 8.70 MILES.
LEVEL
1758'
53 @ 300' AND 54 @ 60' = 19,740' (300' STEEL TRUSS AND 60' TOWER SPANS)
3.3%
3080'
148 @ 60' = 8,900'
60' REINFORCED CONCRETE GIRDER SPANS.
4400'
4.1%
1740'
500'
700'
500'
1040'
4400' (TUBE)
INNER HARBOR CRAWDEL
CLEARANCES 135' OVER MEAN HIGH WATER
SAN
FRANCISCO
BAY
HUNTER
POINT
PT AVISADERO
GENERAL
ANCHORAGE
N. 74° 10' E.
N. 53° 40' E.
OAKLAND
INNER
HARBOR
WEBSTER ST.
ALAMEDA
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG SAN FRANCISCO BAY BRIDGE COMMISSION
HUNTER POINT LINE
SCALE IN FEET
0 500 1000 2000
LOCATION NO. 5
PLATE NO. 5.5
PLAN NO.

Plate No. 54

MAP SHOWING VARIOUS LOCATIONS

79010 10-30 2650


ANGEL ISLAND
Golden Gate
Alcatraz Is.
GENERAL ANCHORAGE
Goat Is.
LOCATION No. 3.
LOCATION No. A.
TUBE LINE
KEY ROUTE MOLE
Outer Harbor
S.P. OAKLAND MOLE
Middle Harbor
S.W.P.R. MOLE
INNER HARBOR
S.P. ALAMEDA MOLE
No. 1.
I-C AND 2.
1-A-B.
EMERYVILLE
CENTER OF PASSENGER AND VEHICULAR TRAFFIC
OAKLAND
Lake Merritt
PRESIDIO
Ferry Bldg.
NAVAL ANCHORAGE
LOCATION No. 1.
LOCATION No. 1 A-B-C.
CENTER OF PASSENGER TRAFFIC
CENTER OF VEHICULAR TRAFFIC
MARKET
Mission Rock
GENERAL ANCHORAGE
FORBIDDEN
EXPLOSIVES
ANCHORAGE
LOCATION No. 2.
PACIFIC ST.
ALAMEDA
Golden Gate Park
SAN
FRANCISCO
Potrero Pt.
GENERAL ANCHORAGE
LOCATION No. 5.
Hunter Point
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
HOOVER-YOUNG
SAN FRANCISCO BAY BRIDGE COMMISSION
MAP SHOWING VARIOUS LOCATIONS
SCALE IN FEET
PLATE NO. 54
F.R.M.